MAKING BIOPLASTICS: AN INVESTIGATION OF MATERIAL-PRODUCT RELATIONSHIPS

Damla Tonuk (BSc, MSc)

This thesis is submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

Department of Sociology

Lancaster University

Submitted February, 2016

Making Bioplastics: An Investigation of Material-Product Relationships

Damla Tonuk (BSc, MSc)

This thesis is submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

Submitted February, 2016

I declare that this thesis is my own work, and has not been submitted in substantially the same form for the reward of a higher degree elsewhere.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

This study explores how bioplastics come into being and are changing by focusing on the relationship between bioplastic materials and the products into which they are made. Bioplastics, which are types of plastics that are made from plant sources and/or can be decomposed by microbial activity, are a challenging set of materials not only because of their variety, but also because of the multitude of industries, actors and socio-technical arrangements involved in their making. I explore the different places in which bioplastics are made; in practices of categorising and standardising and so defining bioplastics, in production and the realisation of bioplastics in everyday life through their substitution for other materials, and in branding where bioplastics are made variously visible, as well invisible, as their particular qualities are enacted in specific material-product relationships.

I draw conclusions about the nature of the relationship between materials and products, how they are separate but also intricately interconnected, at the same time acknowledging that what is named as a material and as a product is contingent upon the stakeholder in the production chain of materials and products. I detail the ways in which materials get shaped by and also shape the standardization and production infrastructures, interests of different actors, competitor materials, and values at stake within their interaction to specific products. The aim of my study is to open up new connections and pathways for the study of materials, as well as objects, within the social sciences.

ACKNOWLEDGEMENTS

First and foremost I want to thank my supervisors, Elizabeth Shove and Lucy Suchman, two exceptional and admirable academics, without whom I would have never been able to accomplish this study. I want to thank them for their enduring patience and for not losing faith in me, at the times I struggled. They have been the ideal guides and role models shaping my academic intelligence and character. I did not know I could still learn so much and improve. They will always remain as prominent figures in my academic life.

Elizabeth's support for my interest in sports and our sports activities together will always remain dear memories for me.

Second, I would like to thank my viva examiners, Tom Fisher and Martin Brigham, for sharing their ideas and wisdom with me, and questioning my decisions and arguments to sharpen these. I also want to thank Luis Araujo, who has acted as my panel member. He has shared his insight with me during this project, and has made valuable suggestions that shaped my thesis.

I want to thank my respondents, without whose generous explanations this research would not be possible, especially to Andy Sweetman from Innovia, Paul Mines from Biome Bioplastics, Remco van der Leij from Zuperzozial, Marc Verbruggen from NatureWorks, and Michael Thielen, the editor of *Bioplastics Magazine* for their time and insightful explanations and for generously sharing their wisdom with me.

I also want to thank Joanne Wood. It is always so much gratifying to meet people who enjoy their job so much. Her belief in me has been invaluable. She has encouraged me to work on my writing and has unleashed the best in me. I learnt so much from her, as well as enjoying her energy and friendship.

I want to thank Mustafa Özakça, for his personal effort in supporting me to pursue my dreams to come to Lancaster. I was funded thanks to his trust in me.

My dear office mate Steve, has been always supportive and has read my drafts and has helped me with his native English skills. I also want to thank my teammates, and coaches, who have made Lancaster home, and made me a proud captain with the successes we achieved.

Lastly, I want to thank my family, my mom, dad and my husband. My parents for always giving me their best, and all. Their support in life for everything. I cannot ever thank them enough. And my husband, Aernout, who has been there for me in everything, for supporting me and comforting me with his love, and giving his best for me. Now, we will go on the trips we always dreamt of.

CHAPTER 1

INTRODUCING BIOPLASTICS AND THE MATERIAL-PRODUCT RELATIONSHIP

We are in the infancy of bioplastics. But I am sure that they will survive and that they will not only survive for themselves, but they will survive traditional plastics, and they will become traditional plastics in the future.

Michael Thielen, editor of *Bioplastics Magazine* and
the author of *Bioplastics: Basics, Applications, Markets*
Quotation from my interview on 10th Oct 2013.

1.1 Main Motifs, Orientation and Positions

This thesis explores how bioplastic materials come into being and are changing, by taking account of their relationship to the products into which they are made. It might sound banal to state the aim of the thesis in this way, without an engaging story explaining the main question or challenges of the topic. Yet this is how I started to investigate the field of bioplastics; asking how plastics come to be 'bio' and why they are made into the products they are made into. It was from that investigation that I discovered the intrinsic challenges of this topic. I also feel it is important to point out that I did not have previous training in any of the social sciences. I come from a practical tradition of product design. This meant that I had to develop a different approach to looking at the relations I was situated in, which is not an easy task. This also partly accounts for the route that I followed in this thesis. In this introductory narrative, by opening up the different parts of the first sentence above, I hope to take the reader on what turned out to be not at all a banal journey, through which a very interesting and dynamic field unfolded, where the study contributes to the traditions of material culture studies and science and technology studies (STS) by calling attention to a new set of relationships, more specifically between materials and products.

The aim of studying materials and objects, more specifically tracing how bioplastics have come into being as stated above, no longer surprises or perplexes the reader of social sciences. Things, non-humans, artefacts, objects, materiality, materials, commodities, or entities that are named differently as a result of differentiated theoretical approaches to their constitution and place in daily lives and social theory, have an established place in STS, material culture studies and the social sciences more broadly, and researchers do not have to defend their interest in the physical elements of daily lives as relevant for social and political theory, and the organization of daily life and practices. Until recently as Shove et al. (2007:94) write 'the grey area between molecular matter and cultural product is such unfamiliar territory that it is difficult to know quite where to begin.' Now, after a decade, there is an array of theoretical and practical traditions with which to study materials (or more broadly objects). (See Shove et al., 2007, for an extensive summary of approaches to objects within different disciplines.)

I was interested in a sociological approach to materiality as a result of my encounter with material culture studies, particularly within the contemporary anthropology of Miller (2005, 2010), and with the work of Shove, Watson, Hand and Ingram, entitled *The Design of Everyday Life* (2007), which rests at the intersection of material culture studies, STS and practice theory.

These approaches attend to objects as unique assemblies of relations. However, the empirical orientation of these studies are mainly focused on the use of materials and objects by subjects within their daily life practices, after these materials are produced into a certain product form. STS and scholarship that is informed by STS attends to larger networks of relations that are folded into objects and especially attends to larger units of analysis compared to individual daily lives and identity (Latour, 2005). Approaches from STS, mainly those of Hawkins (2009, 2011a, 2011b, 2013a), Marres (2008, 2012a, 2012b, 2014), Barry (2005), from political philosophy (Bennett, 2010), and from the sociology of marketing (Callon et al., 2002; Callon and Muniesa, 2005) allow me to see the materials (and the products) as *made* in their relations rather than as already there, found and extracted with intrinsic qualities. As well, this literature allows me to see materials themselves as active agents both being shaped by but also shaping the relations of which they are a part (Bennett, 2010; Hawkins, 2013a). Seeing materiality as an active element of politics (Bennett, 2010; Gabrys, 2013; Marres, 2012a) or as a crucial element in the organisation of markets (Callon and Muniesa, 2005, Callon et al., 2002) allowed me to better grasp and analyse bioplastics and the different actors involved in their making.

So my study is placed between material culture studies and STS. However, the opening sentence specifies further that I am specifically interested in the nature of the relationship between 'materials' and 'products'. To suggest that they are different elements but that there is a relation between the two, and that products makes materials as well as being made out of them, is the novel contribution of this thesis. In this sense my thesis is an intervention to these disciplines and establishes new connections that I argue should be taken into account in studies of materials (and also of objects). Also I offer focusing on substituting and making visible as the practices that my method attends to. These methodologies can be used to explore the making of other categories of materials such as metals and woods, as well as bioplastics.

Before I move further I need to clarify my usage of the terms ‘materials’ and ‘products.’ At the beginning of this study, the distinction between these terms appeared self-evident to me as a designer. They are treated as self-evident in the design literature as well, and their relationship is rather straightforward; products are made of materials. In the sociological literature, however, there is an ambiguity in the usage of the terms ‘materials’ and ‘products.’ Both are referred to with a range of rather vague terms within different approaches: as objects, things, or materiality within material culture studies, as material or matter in political philosophy, as technologies, devices or non-humans within STS. Since the relationship between ‘materials’ and ‘products’ has not been the focus of much scholarly interest, their nuances are often overlooked and they are often used interchangeably. Even in the social and cultural accounts that are specifically studying materials, despite the fact that the terms ‘materials’ and ‘products’ are used, they are often used interchangeably (Katz, 1978; Manzini, 1986; Meikle, 1997a; Wahlberg, 1990). So, in my study by carefully working through these terms, despite their position as self-evident in design literature and as interchangeable in social sciences, I try to articulate their difference, but also to show the ways in which they are intimately interconnected.

I use ‘materials’ to refer to a particular molecular structure and distinctive material substance of things, such as wood, metal, plastic. However, it is important to note that ‘wood’ or ‘metal’ are culturally constructed categories themselves, and my study uses these familiar categories to position the emergent categories I am working with. When I refer to the general category of a material I use it in the plural, as in ‘materials.’ However, if I focus on a particular type of material, such as polypropylene (PP) within the broader category of plastics, then I use it in the singular, as in 'the material.'

Although the sociological literature talks about mass produced market goods, such as bottles, bags, spoons, computer mice and mobile phones, as objects, things, non-humans, or materiality, I prefer to use 'products.' I refer to Callon et al.'s (2002:197) clarification derived from the literature of economics to elaborate on my usage of the term:

> The concept (*producere*: to bring forward) shows that it consists of a sequence of actions, a series of operations that transform it, move it and cause it to change hands, to cross a series of metamorphoses that end up putting it into a form judged useful by an economic agent who pays for it.

Products thus imply a transformation, from material substance, to a useful economic agent. This in a way provides me a starting point to conceptualise the relationship between materials and products: products are materials *transformed* through manufacturing processes. While they are still materials, they are changed into something defined by a different set of relations and associations than that of the material.

My interest in focusing on the relationship between materials and products originates from a relatively ordinary observation. There are no bioplastic granules out in the streets, they are always made into a consumer product. In other words, we as ordinary consumers do not interact with 'bioplastic granules' but with a 'bioplastic salad bowl.' Also there cannot be a market for these materials without the products. This pointed to an inevitable and almost obligatory relationship between the two, and means that, in very rough terms, those who are making the ‘materials’ *must* somehow *transform* them into particular ‘products’, for which consumers are willing to pay.

This relationship is also mentioned in a special issue of the journal *Archaeological Dialogues*, where Daniel Miller, Christopher Tilley and Tim Ingold write specifically about materials. Ingold (2007a:9) in this issue explains:

> It is the objects themselves that capture our attention, no longer the materials of which they are made. It is as though our material involvement begins only when the stucco has already hardened on the house front or the ink already dried on the page. We see the building and not the plaster of its walls, the words and not the ink with which they were written.

According to Ingold, products appear as obstacles to apprehend materials, until materials ‘break.’ I suggest that this taken for granted and invisible status of the materials is the very reason to explore them sociologically, and that this exploration will open up new pathways and connections for the studies of materials as well as objects. I propose that there are still some insights for the studies of materials (as well as objects) from attending to the differences as well as interrelations between materials and products, and that attending to the subtleties of material-product relationships might contribute to a deeper understanding of materiality within the social sciences.

Two studies, which I will refer to extensively later, are closely related to my purposes in this thesis, and these studies make useful guides as well as a starting point for my analysis of the relation between materials and products. Schatzberg’s (2003) account of a business history of aluminium acknowledges the fact that aluminium was used in different industries, such as aviation and packaging, in and through which different meanings and associations of aluminium were produced that contributed to a general image of aluminium. Shove et al. (2007) come the closest to the aim of my thesis in their chapter entitled 'The Materials of Material Culture: Plastics.' They acknowledge that materials and products are different entities, and by means of their historical account of plastics they conclude that the relationship between materials and products is that of co-constitution of symbolic and material aspects. However closely aligned to my own, these studies do not provide a comprehensive account with which to develop on my specific focus. Therefore, in the following chapters I draw on a variety of other approaches to open up the issues that are raised in relation to the practicalities of making bioplastic materials and their relationships to products.

Before turning to the materials (and the products) that are the topic of this study, however, I want to return to my opening sentence once again and draw attention to the wording in 'how bioplastic materials come into being and are changing' as opposed to 'came to be.' My account of materials is not an end in itself. As I hope to show, the making of materials is a constant becoming. So, my analysis in this thesis will give an insight into a particular moment in the story of the emerging field of bioplastics, and from a certain perspective. Accordingly, the conclusion of this study is not a comprehensive or static map of the relations making bioplastics, but rather an exploration of these relations and discussion of their implication.

1.2 Bioplastics, Complexity of the Field, and Implications

This section introduces the diversity of the field and the different areas that bioplastics touch. I will write more about bioplastics in Chapter 3 in terms of the various supply chains involved, but here I seek to give a sense of the complexity and multiplicity of the field, in terms of the types of materials, the range of products into which they are made and the variety of industries and actors involved. I feel that I should state at the outset that as much as one learns and thinks about bioplastics, the feeling of not being able to grasp it and that it slips out of the hand grows. So at the end of this section I will arrive at a rather partial picture of a complex and dynamic field.

Bioplastics can be defined as the materials (more precisely types of plastics) that are biobased and/or biodegradable. Briefly, bioplastics' source of carbon, which is the fundamental element of which any type of plastic is made, is renewable biomass, i.e., plants such as corn, potato, algae and the like, thereby making them 'biobased.' At the disposal end the materials dissolve into carbon atoms that can be digested by microorganisms, making bioplastics 'biodegradable.' Bioplastics are not only one kind of material, however. Rather they define a family of materials, as is evident in my scan of *Bioplastics Magazine* from 2006-2014: Polylactic Acid (PLA), Polyhydroxyalkanoates (PHA), Thermoplastic Starch (TPS), Bio-urethanes (BUR), ligno-cellulosic materials, nano-biomaterials and the like. Moreover, these materials have distinct characteristics, and each material has different grades that can have quite different properties. As just one example, different grades of PLA can be engineered to be non-biodegradable as well as biodegradable.

Although some types of bioplastic materials have been around for about a century, only after 2005-6 were they first named as bioplastics, which also arguably created 'the bioplastics industry' by uniting differently interested groups under a single category. After some initial struggles and failures in the 1990s (Lubove, 1999), in the 2012 Conference report of Plastics

Technology,[1] entitled '*Bioplastics are Breaking Out of their 'Green' Niche,'* bioplastics are announced as 'not a mere fad, a 'green' public relations stunt, or feel-good eco-luxury, but legitimate tools of industry.' During the last decade, bioplastics have established their place as a rapidly growing industry. There are different growth figures, from which I chose to present the figures from the European Bioplastics Association that are based on statistics from Nova Institute.[2] In 2012 bioplastics defined a small market with 0.8 million tons of bioplastics production, compared to 288 million tons of traditional plastics production, which equals a market share of about 0.2 percent of traditional plastics (Thielen, 2012). However, bioplastics are rapidly growing and present a promising field to investors, with a growth rate of 20-25 percent a year, whereas traditional plastics are growing between 4-9 percent per year (Thielen, 2012).

Having made this very brief introduction to the variety and the growth of the field, it is important to acknowledge that there is no consensus on a definition of bioplastics or on the definitions of the terms 'biobased' and 'biodegradable' among the different groups that are involved in the field. *Bioplastics Magazine*, the largest international trade magazine in the field, recently opened up a debate on whether bioplastics should necessarily be both biobased and

---

[1] Plastics Technology is an online information platform that provides news, articles, newsletters, supplier profiles, research analysis regarding plastics. Accessed from http://www.plastics-technology.com/aboutus on 6thOct 2015.

[2] Nova Institute; Institute for Ecology and Innovation, Germany. 'For the last two decades, the Nova-Institute has been globally active in feedstock supply, techno-economic evaluation, market research, dissemination, project management and policy for a sustainable bio-based economy' (Retrieved from http://www.nova-institut.de/bio/index.php?tpl=novalist&lng=en on 15thAug 2015).

biodegradable, or whether either biobased or biodegradable materials could also be regarded as bioplastics.[3] The terms biobased and biodegradable themselves are debated as well; the characteristics of the source, percentage of this source to qualify as biobased, production methods, life-cycle assessment methods, the nuances between degradation, biodegradation, compostability and home-compostability are topics of controversy.[4] These discussions often refer to definitions from standards organisations, such as The American Society for Testing and Materials (ASTM), and the International Standards Organization (ISO). These standards seem, if not to resolve, at least to settle the controversies, to the benefit of some groups.

It is sufficient for now to point to the contests of interests to capture the ambiguity of the field. This ambiguity appears to be one of the tension fields through which bioplastics get made. So I note this problem of defining bioplastics as an important place in the making of bioplastics to attend to: Who defines what to include in the category bioplastics and how?

A brief look at the controversies around defining bioplastics reveals the multiplicity of actors that have an interest in the field. Different types of bioplastics relate to different industries and different groups. To start with, biobased bioplastics radically challenge the relationships between the oil industry and the petrochemical industry, as bioplastics depend on agricultural

---

[3] Bioplastics Magazine, 02/2006, 'Editorial' by Michael Thielen.

[4] Business-NGO Working Group for Safer Chemicals & Sustainable Materials, 2007 in Álvarez-Chávez et al., 2012:48; USDA, The US Department of Agriculture, 2005; The Biodegradable Products Institute, 2006 in Álvarez-Chávez et al., 2012:48; Mojo, 2007; ASTM, the American Society for Testing and Materials in Mojo, 2007; DiGregorio, 2009.

production rather than petroleum. Arguably, this attracts attention in some regions within government and economic development plans regarding oil dependency. For example, the US Department of Agriculture (USDA) and the US Federal Trade Commission have initiated the 'BioPreferred Program', where government organisations were obliged to buy biobased products.[5] Governments, certain industrial sectors, interested organisations, and NGOs all variously participate in the making of the materials. Also production sites such as the plantation sites and various manufacturers, as well as other bio dependent industries such as biofuel, come into relation to bioplastics.

Biodegradability represents yet other interests in the field. The different end-of-life options offered by biodegradable plastics relate to different practices and interests of incineration, composting, and recycling organisations and infrastructures. Within different regional, political, economic and environmental interests, various governmental organisations, NGOs, and social groups participate in defining and so in the making of bioplastics. These include the Biodegradable Products Institute, the health-care industry, waste management groups and the like.

Environmentalist movements, government bans, standards updates and new legislations have also played an important role in the implementation of bioplastic products on a large scale; for example governmental bans on plastic carrier bags in Italy brought about a market

---

[5] Information accessed from http://www.biopreferred.gov/BioPreferred/faces/pages/AboutBioPreferred.xhtml on 9th Sept 2015.

for bioplastic as well as paper alternatives.[6] Some regulations also force industrial management to develop strategies that involve material choices to maintain their commercial strength; for example, the government cafeteria of the Indiana Government Center in the United States, which serves 8,000 employees, switched to disposable bioplastic cutlery and tableware.[7] It was seen as a rewarding implementation for waste management, since biodegradable disposables could be thrown away together with food waste, without requiring an additional step of waste separation for recycling.

These examples show the broad scope of the field in terms of the related actors ranging from research organisations to governments and various industries and their environmental, commercial and organisational interests. However, values and traditions around existing materials are also relevant in the making of bioplastics. The different sourcing, disposal and regulation regarding bioplastics construct a different set of relationships and dynamics than that of the contemporary plastics industry, and challenge many of the negative connotations of contemporary plastics as a material. These definitions touch on the juxtaposition of materials and challenge material taxonomies, which is one of the issues that this thesis addresses. Specifically, I am interested in finding out how materials are made through their relations to products and interested actors, as well as other materials.

---

[6] Information about plastic bag bans in Italy, accessed from http://www.plasticsnews.com/article/20130610 on 9th Sept 2015.

[7] *Foodservice Director*; Jan 15, 2009; 22(1), p12, Pro-Quest Business Collection, 'Government Center Cafeteria to Use Bio-plastic Containers.'

Still the complexity of the field, the main qualities of bioplastics, and the different human and non-human actors involved do not explain why bioplastics are valued as ‘bio.’ On the one hand, plastics in the media have always been represented as the opposite of bio; they are wasteful, harmful for the environment, polluting waters and accumulating in the ecosystem with lethal effects. On the other hand there is no direct reason why the features of being biobased, which basically means to ‘use up’ nature’s resources, and biodegradation, which simply means that the material cannot hold its molecular composition and ‘decays’, come to be valued as environmentally friendly features.

Indeed these qualities are taken up differently by different actors. On the one hand, bioplastics are positively valued within heightened environmental controversies over plastics, and the various issues of concern that plastics raise such as waste, water contamination, and health risks. Bioplastics get invoked within a market place where products and services compete for lower carbon footprints, for lower negative environmental impact and for more sustainable and environmentally friendly processes. Being biobased, which means that the oil content of plastics is replaced with bio-sources, is valued as more sustainable and as economically more stable alternative, against the threat of the oil crisis and increasing oil prices (Ren, 2003). Biodegradability is valued as a solution to the global waste problem, condensed around plastics (DiGregorio, 2009). Mobilising these qualities within environmentally friendly discourses as a result of material-product relations makes bioplastics ‘bio.’

On the other hand, some groups attribute negative values to these features. Composting and recycling facilities and organisations are sceptical of issues to do with sorting bioplastics from other materials, or the potential contamination that bioplastics might lead to. There are debates on the ethics of production, since bioplastics might compete with the land for growing food for human consumption, and some groups argue that edible products in any case should be used primarily to serve those in need rather than to produce more consumer goods. Although some of the companies set up their own plant production sites, the ethical aspects are discussed by human rights organizations, since they support the idea that these lands and the resources to cultivate them should in any case be used for human welfare.[8] Another critique is that significant amounts of energy and water are used for the production sites. Furthermore, there are discussions on GMOs and hazardous chemicals that are used in fast growing plant sites, which raise issues of sustainability and environmental concerns. These different valuations call for research organisations to take part in the bioplastics field, as actors informing controversies.

These observations lead to two important themes to be explored. The first one is to look at the *processes* through which the values of materials (and products) are defined and negotiated that makes the materials. Defining value is an articulation as well as a negotiation among differently interested groups of materials producers, brands, various environmental groups and NGOs with different priorities. And the second theme is the *outcome* of these valuation processes and to realise that these outcomes reproduce materials further. The bioplastics industry develops through the representations of and reactions to bioplastics in different industries and social organizations; for example, as my interviews and survey of the magazine showed, the source of bioplastics currently seems to be shifting towards cellulose, which

[8] *Bioplastics Magazine*, 2009/4. In the article titled: 'Land Use for Bioplastics' contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

comes from old trees, or industry waste sites, as opposed to plant sources that can as well be a food source, as a result of valuation of biobased as using up food sources.

The multiplicity of bioplastics gets even more complicated when we take into account that different types of bioplastics are made into a range of different products, from consumer products, such as mobile phone casing and automobiles, to food packaging, to specialist applications, such as bone scaffolds or support material for rapid prototyping. In addition, each product has a life of its own, in terms of the industries and groups involved in its making, its meanings in relation to the product category (as opposed to the material category), and the practices of which the products are a part. As such the relations are reproduced with every material-product combination.

In sum, bioplastics and the products they are made into proliferate complex relationships, in terms of materials, industries, infrastructures, valuations and end products. The emerging and varied material culture of bioplastics implies new organizations of people, practices and things. The new materials change the organization and material capacities of daily lives by substituting for existing materials, as well as reproducing symbolic possibilities. Moreover, the growing possibilities bring along different interests in different forms and stages of the material-product relationship, which are enacted through the creation and valuation of categories (Bowker and Star, 2000; Busch, 2011), material politics (Gabrys et al., 2013), competition, and regulation.

The purpose and the challenge of this thesis is to explore the relationships between materials and products within the multiplicity of the bioplastics field, by unfolding the material and social arrangements through which bioplastics are enacted. To do so, as I will explain extensively in the next chapter, I chose to focus on substituting materials and making them variously visible across different sites of production as strategies that let me in the field and show me the stakes around bioplastics.

1.3 Structure of the Thesis

The next two chapters (Chapters 2 and 3) form a basis for the analysis of the empirical material that will follow. As well as explaining in more detail my conceptualisation of materials and the empirical research on which this study is based, these chapters also provide a guide to connections between the theoretical framework and the empirical materials.

Chapter 2 elaborates on my conceptualisation of materials, based in various disciplines, of which the most relevant are material culture studies and STS, as well as the sociology of markets, to be able to understand bioplastics that are spread across fields that fall within different disciplinary interests. Chapter 2 develops a basic understanding of materials as *made*, as opposed to readily available and already there, and their properties as *articulated* in their relations to both human and non-human environments. Such a conceptualisation requires a methodological strategy that will capture the materials in the making and enable me to delve into their relationships to products. So, I also elaborate on the methodological strategies that give me access to this fluid and dynamic field.

Chapter 3 explains the empirical basis of this study and discusses the status of the data that informed my analysis. In accordance with the conceptualisation of materials as made, the thesis explores the worlds in which bioplastics are *enacted*. As stated earlier, the different worlds of bioplastics are organised through its production and supply chains, and I take these to be the places where the material-product relationship is formed. Building on a thorough investigation of the supply chain of bioplastics, the chapter then proceeds to explain and discuss the sample of sites and cases chosen, how the interviews were arranged, organised and conducted, and how data were collected and analysed.

These initial chapters build a theoretical framework for the thesis, and elaborate on the methodological strategies that are in line with this framework. A more detailed account of my empirical research is presented in the subsequent three chapters (Chapters 4-6). As I have indicated, bioplastics are multiple, in terms of the materials, products, industries, networks and practices in which they are enacted. Therefore, the empirical analysis is also multifaceted and the processes of production are by no means linear, as they feed back into each other. However, I chose to structure the narrative of the analysis of the empirical material to follow the conventional progression of supply chain and production to capture the interface between materials and products, as materials are transformed into products and specific material-product combinations are configured.

The empirical analysis begins with defining and categorising bioplastics (Chapter 4), then explores the production of bioplastics into products (Chapter 5), where materials are physically transformed into products, and finally elaborates on branding bioplastics in specific material-product relationships (Chapter 6). Each of these chapters explores a different world of which bioplastics are a part; as such these chapters can stand alone, each giving insights into a particular setting through which bioplastics are enacted, or they can work together to draw a more comprehensive picture of making of bioplastics in separate but interacting worlds.

Chapter 4 looks into the ways in which bioplastics are defined in generic categories and formal standards. I explore the category bioplastics, the sub-categories biobased and biodegradable, and European and American standards, according to which materials are certified and labelled as biobased, or compostable and the like. However, by using particularly the studies of Bowker and Star (2000) and Bush (2011), I see that categories and standards are made and changed by actors. Therefore, by examining the ways in which categories of and standards pertaining to bioplastics are made and changed, I unfold the actors and the interests that are involved in making the field.

In Chapter 5 I examine the transformation of the category bioplastics into products, and the processes of material substitution, as I take these to be the main route through which materials are realised in daily lives, as well as one of the main places in which material-product relationships are formed. However, I consider that these processes are not only a straight-forward technical production, but are also comprised of social processes through which materials are compared, positioned against each other, and qualified-requalified, using Callon et al.'s terms (2002). I exemplify my analysis with the case of the production of one of the first bioplastic products – water bottles – and elaborate on how qualities of a particular type of bioplastic are enacted in relation to products, production equipment and other materials.

The last empirical chapter, Chapter 6, explores the ways in which materials are made visible in products, as this seems to be a primary way in which specific material-product relationships are configured, as new relations are created for the materials and new terms emerge with which products are judged. This shows as well the ways in which materials are remade in specific material-product combinations, and the ways in which materials and products interact, in terms of identities and qualities of materials and products. I look at illustrative cases including the compostable waste bags of the municipality of Milan, the compostable coffee pod, the biobased packaging bottle of Ecover, and the bioplastic tableware range of

Zuperzozial where materials are made visible in various ways; such as the visibility of the material, its qualities and the problems to which the material offers a solution.

The concluding chapter brings the arguments raised throughout the thesis together. It also places these discussions back into the related literatures, including STS, material culture, and design, and in larger debates about sustainability and innovation.

CHAPTER 2

CONCEPTUALISING MATERIALS AND DRAWING A FRAMEWORK TO STUDY BIOPLASTICS

> …a new plastic such as PET was not simply a product of contingent, path-dependent processes of industrial development and translation, but also an event, a novel entity, in which the molecules of plastic revealed new associations and ways of relating.
>
> (Hawkins, 2013a:54)

The previous chapter introduced the focus of the thesis on how bioplastics come to be, and more specifically attending to material-product relationships to unfold the relations making materials. It also briefly described bioplastics as a challenging set of materials; emergent, fluid and continuously in the making. The current chapter aims to develop a conceptualisation of these relations by elaborating on the starting premises I adopt that enable me to analyse bioplastics within their multiplicity. It also discusses the methodological implications of this conceptualisation and explains the methodological strategies I developed to explore the making of bioplastics and their relationships to products.

Materials like aluminium, plastics and bioplastics have extensive and far-reaching careers, from sourcing to production and consumption, and related technologies, markets, economic development plans, business strategies, politics and the like. Consequently, materials have been studied by various disciplines, from within various disciplinary traditions, from social sciences and history to design and engineering. However, as mentioned before, studies on materials from social sciences are rather limited in number. In addition, these studies do not necessarily distinguish between materials and products in the sense that I want to analyse them in my study. Moreover, except for the two studies I identified earlier – Schatzberg's (2003) account of aluminium's different symbolic meanings in different sectors (and so product domains) and Shove et al's (2007) chapter which focuses on the relationship between plastic and its changing symbolic meanings, the products that plastics are made into, and related practices – the relationship between materials and products have not been accounted for. This is the gap that I hope to address with my study. With that aim, this chapter develops a conceptualisation of materials that enables me to address their relationship to products. While each of the following chapters provides a more specific theoretical framing that addresses the changing focus of each chapter, these conceptualisations expand on the starting premises adopted here.

In order to set out my basic conceptualisation, in Section 2.1 I briefly review some of the approaches from design and social sciences. I critique the approach of design professionals and the design literature, as well as some social and cultural histories of materials, insofar as these approaches take materials as given, already there and as passive elements of forces acting upon them. These approaches are problematic for my study, given the varied and dynamic nature of bioplastics. I draw on ideas from material culture studies, STS and literature informed by STS to offer an alternative way of conceptualising materials as *made* in their relations, where materials are *active* agents in these relations. The studies I draw on in this chapter are not talking about materials per se but rather about objects, as studies of objects within the social sciences have better established traditions and lines of enquiry.

This conceptualisation of materials prompts me to think about 'properties' of materials that are taken as given, definitive and intrinsic in the design and cultural history approaches. Drawing on the ideas of Callon and Muniesa (2002) and Callon et al. (2005) from the sociology of marketing/STS literature, I conceptualise the properties of materials as *made* and *articulated* in and through the various relations and within the multiple environments in which materials circulate (Section 2.2). Next (Section 2.3), I move on to think about the relationship between materials and products, drawing upon the concepts I have developed to address the making of materials and their properties.

This conceptualisation and the analysis of bioplastics requires me to develop as well a set of methodological strategies to guide my research and organise my empirical material (Section 2.4). To be able to study the complexity of bioplastics and relations surrounding them, I focus on two practices of producers and brands in the making and positioning of bioplastic materials. I argue that these strategies of the companies are also useful methodological strategies for me to follow in order to understand how bioplastics are made and the dynamics of their relationships to products. The first is 'substituting (existing materials with bioplastics)' and the other 'making visible or invisible.' I explain the ways in which substituting, which implies putting one material in place of another, breaks down instances of making, stabilizes relations temporarily, and brings different interests into perspective, and hence presents itself as a useful methodological strategy to explore the field of bioplastics. Additionally, I argue that the concepts of visibility and invisibility allow me to see what is valued and what counts in and across processes of substitution.

I conclude this chapter (Section 2.5) by discussing the directions in which this conceptualisation and methodological strategies point me, and explaining how these inform the rest of the thesis and allow me to explore materials-in-the-making.

2.1 Conceptualising Materials

Designers are the professionals who are expected to envision the processes in which materials are transformed into products; that is, into usable, useful social entities. However, the design literature has been inattentive to the study of materials as such, and the design discipline is informed by 'material selection tools', developed by engineering disciplines, that contain information mostly about the mechanical characteristics of materials (Karana, E., Hekkert, P., and Kandachar, P., 2008, 2009). In the last decade, among design academics, there has been a renewed interest in materials and their importance for the user's experience of products (Ashby and Johnson, 2002; Karana, et al., 2008, 2009; Pedgley, 2009). These scholars have explicitly emphasised the role of materials for the 'satisfaction of users' with products and for 'designing desired relations' (Karana, et al., 2008, 2009). Karana, who has worked extensively on developing 'material selection tools' that are better suited to design processes, has argued that information about 'intangible properties' (the symbolic meanings attributed to materials such as cuteness, sexiness, warmth to the touch) as well as 'tangible properties' (technical and mechanical properties such as permeability, ductility, heat resistance that can be measured by means of technical devices and read out as numerical values) should be contained in those materials selection tools, as materials have both tangible and intangible properties. The idea is that the designers use these tools or guidelines to ‘select’ materials for their products by being attentive to these intrinsic properties and the meanings materials are believed to carry.

From its inception the design profession seems to have taken on a role that is practically impossible to fulfil, that of embedding products with certain meanings and messages, since the meaning of things are constantly changing in the different worlds in which they circulate. As Fisher (2004) in his study of plastics shows, new meanings of plastic have emerged in its interaction with users. Moreover, the design approaches tend to take meanings as fixed by the materiality of materials. In addition, materials are dominantly seen as ‘given’ and ‘complete’, both by the practitioners of design and production (as my interviews revealed), and in the theoretical approaches from the design literature. Materials are – in such approaches – found and extracted with their intrinsic properties, and, as a logical extension of these properties, materials are made into certain products. This disregards the ways in which the technical qualities of materials are defined and are inevitably dependent on the testing equipment and social and technical arrangements of testing organisations. Such limited perspectives on materials and their properties are problematized by scholars from different disciplinary traditions as wide as philosophy, material culture studies, STS, business history and marketing (Bennett, 2010; Callon and Muniesa, 2005; Hawkins, 2013a; Schatzberg, 2003; Shove et al., 2007). Shove et al. (2007:97) state that:

> …materials […] do not exist outside society. They are not ‘just there’ waiting to be exploited, discovered and appropriated. In materials science, as in other areas of scientific endeavour, lines of enquiry and pathways of innovation are nudged this way and that by socially and historically specific patterns of investment, interests and enthusiasm.

In the design literature there are more nuanced approaches. Pedgley (2009) emphasises that the supply chain, in terms of available or customary materials, is influential on the 'selection' of materials. However, he does not regard the supply chain relations and various dynamics within them as 'constitutive' of materials. In these approaches, materials are 'given' and circulate already finished, while the social and technical arrangements in which the materials are situated and of which they are a part are out of the scope.

Cultural and historical accounts of materials (Handley, 1999; Katz, 1978; Meikle, 1997a; Wahlberg, 1999) provide me with a starting point to think about materials within their social relations. As just one example, Handley in her historical account of nylon with respect to the history of fashion demonstrates the ways in which nylon developed in and through social transformations – changing conceptions about convenient clothing, nylon stockings, changing fashion trends and conventions about grieving, the creation of the female consumer. I elaborate on the broader arrangements into which materials must fit with an example from Harvey Molotch's book *Where Stuff Comes From* (2003). For Molotch (2003:1), 'each element is just one interdependent fragment of a larger whole.' Molotch (2003:1) expands on this idea with the example of a simple toaster that is a common item in most British houses:

> [The toaster] does not just sear bread, but presupposes a pricing mechanism for home amperage, government standards for electric devices, producers and shopkeepers who smell a profit, and people's various sentiments about the safety of electrical current and what a breakfast, nutritionally and socially, ought to be.

He goes on to explain that an official system protecting the patents related to this product, ensuring that the standards are adhered to, must be in place. He observes that all the ingredients of a toaster must be present at the same time in order for it to *be* a toaster. Although his study focuses on objects rather than materials, it is still helpful in demonstrating the 'larger whole' of which any one object, or material, is a part.

Studies of materials that approach them as a way of exploring dimensions of technological and social change also portray the complex relationships between different industries, investors, businesses, political and governmental bodies, patent and standardisation infrastructures, inventors and chemistry laboratories, through which materials come to be (Bijker, 1995; Meikle, 1997a; Misa, 1995; Schatzberg, 2003).

With these studies I do not to suggest that materials are simply socially constructed, but rather I seek to place them in 'the larger whole' using Molotch's (2003) terms, in their social environment, to contrast the views of design that takes materials as given and complete. With this initial framing in mind I want to direct my attention more closely to materials as molecular structures, and elaborate on the implications of the above conceptualisations for thinking about the molecular composition of materials. I draw on Bensaude-Vincent and Stengers' (1996) historical account of chemistry, which brings me closer to grasping the material composition of bioplastics. Bensaude-Vincent and Stengers state that materials do not exist in isolation; on the contrary, even molecular formations hold information about their technical and social environment. They state that the position of chemistry and the materials it produces are continually redefined by the materiality of the laboratory, institutions that are in relation with chemistry and its products, and meanings assigned to these. Bensaude-Vincent and Stengers emphasise that even the formations of molecules, or from a common sense point of view materials, are embedded with information about the human and non-human environment, where these environments are constitutive of the materials. Barry (2005), in his study examining the making of pharmaceutical materials, expands on the ideas of Bensaude-Vincent and Stengers, arguing that materials are already informed by the environment in which they will find a place; i.e., in terms of standards, technical and social infrastructures. Barry makes a distinction between discovery and the processes of invention, where he counters the view of materials as discovered and argues that materials – matter, as he sometimes prefers to name molecular structures – are not given nor are they discovered, but rather are *made* in the processes of 'invention' in and through relations, in his specific case, between chemistry laboratories, data infrastructures, pharmaceutical companies, testing organisations, standards and the like. An important implication of these two studies is that the making of materials is seen as comprised of multiple processes, suggesting varying relations between different groups with different interests and non-humans.

Making a distinction between discovery and invention is a useful point to think about the making of materials and things in general. Bijker in his various studies of the technological development of different artefacts explores the 'diffusion stage' of technologies (Bijker, 1992; Pinch and Bijker, 1984). Pinch and Bijker (1984:416) state that 'the "invention" of the Safety Bicycle is seen not as an isolated event (1884), but as a nineteen-year process (1879-98).' Bijker (1992:97), in his account of the social construction of fluorescent lighting, explains that in the 'diffusion stage' of fluorescent lighting the 'process of invention continues,' in that invention is a process in which the fluorescent lighting is constantly remade by controversies between Mazda, the lighting company, and utilities.

Using the studies discussed so far, I locate bioplastics in a dynamic environment of social and technical processes, none of which can be separated from the others. Adopting Bijker's ideas of how technological artefacts come to be, I see the initial stages of the introduction of bioplastics as a process in which materials are iterated and articulated, and so actually made. Rather than studying bioplastics as a ready-made or pre-existing class of materials, this suggests that I must look at the processes and interactions with actors through which bioplastics come to be as they are.

Building on the ideas above I introduce the perspective of Bennett, in her political philosophical account of materials entitled *Vibrant Matter: A Political Ecology of Things* (2010), where she places materials as 'active agents' of social lives. Bennett criticises a view of materials as 'passive victims' of external forces that are shaped by those who are involved in their making: on the contrary, according to Bennett, materials are 'vibrant' and are active in shaping the relations they are involved with. Bennett (2010: viii) names this the 'vitality of materials', where vitality refers to the 'capacity' of things 'not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities, or tendencies of their own.' She uses the term agency in a Latourian sense, and sees matter as an agent, an active force shaping the action that it is involved in.

Although these ideas about agency of the material might sound radical, Bennett (2010) takes the agency of materials even further. For her, the agency of materials is no different than that of 'humans', who she refers to as 'life.' She says that a 'life' 'names a restless activeness, a destructive-creative force-presence that does not coincide fully with any specific body' (Bennett, 2010:54). And she maintains that materials are also 'life', just as much as human beings. She exhausts the object and the subject duality and actually reduces them to one and the same thing, where humans are just another material composition. Hence, materials are 'a creative materiality with incipient tendencies and propensities, which are variably enacted depending on the other forces, affects, or bodies with which they come into close contact' (Bennett, 2010:56).

The current turn to materiality within material culture studies provides me with an angle to elaborate further and bring together these ideas of materials as made in their relations and as active agents. Although the scholars I draw on here (Miller, 2005, 2010; Shove et al. 2007) are mainly supported by an empirical analysis based on consumption and everyday relations of individual subjects with already produced materials, their conceptualisations help me to bring the vitality of material together with its broader relations.

Miller (2005), in his material culture/social anthropology approach, looks at what ordinary people do with a given, already mass produced product; how they appropriate materiality during the course of daily life and construct who they are, rather than looking at how things come to be as they are. It is also relevant to state that material cultural studies (see Banerjee and Miller, 2003; Webb, 2005, for exceptions) rarely focus on the 'materials' from which objects are made. Nevertheless I find Miller's (2010, 2005) problematisation of the object subject duality helpful for my conceptualisation. Miller (2010) rejects the duality between objects and subjects, which I can think of as those of who make/use the object and the object itself. Such a view directs his studies (as well as mine). He maintains that he does not study the objects and their relations to subjects in an anthropological sense as understood generally, but rather he studies the practices and relations through which objects and subjects are 'mutually constitutive.' Hence, the term *materiality* can be understood as a term that he adopts to escape the object/subject duality through a relational constitution.

Building on Miller's idea of mutual constitution between materials and subjects or between humans and non-humans, I incorporate the views of Shove et al. (2007) to expand on the scope of non-humans. Shove et al. (2007) in their study, working between the disciplinary traditions of material culture, practice theory and STS, rehearse the active role that objects play in shaping everyday activities and social relations, by enabling (or limiting the scope of) action. They draw attention to radical views of the agency of objects as the sole facilitators and enablers of social practices and daily life, but then draw a more subtle account of agency. They state that material objects are actually 'useful' items in the 'accomplishment' of daily practices. They emphasise that objects, by physically being there, as well as through their symbolic meanings, shape (enable/limit) action (Shove et al., 2007; Miller 2005, 2010; Latour, 2005). They make use of the conceptualisation in STS that the agency is 'distributed' over humans and the non-human in question, and state that as well as the relationship between humans and non-humans the relationship among non-humans are significant (Shove et al., 2007:11):

> If we are to study the stuff of everyday life, we need to pay equal attention to the ways in which artefacts relate to each other and to the part humans and non-humans play in configuring variously stable material taxonomies and variously durable systems of objects.

This is useful to situate materials as always relational to humans and other non-humans i.e., other materials and objects. The implication of this is that in studying bioplastics, I cannot see them in an isolated environment of only the makers and the material. Bioplastics are situated amongst other materials as well as other objects. This means that I need to see the agency and making of bioplastics in relation to paper, glass, aluminium and other types of plastics, such as PET and PP, and also in relation to tableware, packaging or the 3D printing filament they are made into.

Shove et al. (2007) use the term ‘co-constitution’ to understand the interaction of materials with their environments. Although their accounts are those of the users of mass produced goods and my account is more about the making of materials, the co-constitution idea can be usefully applied to the supply chain of bioplastics, which consists of different users of bioplastics and different objects and materials with which bioplastics interact. I use the term ‘interaction’ to emphasize the agency of all entities involved and to imply that all entities are active, have an effect on each other and also get influenced by each other. By combining the approach of Shove et al. (2007) and Miller (2010) on objects, I look at the mutually constitutive interactions between humans and other non-humans in the process of making both products and materials.

2.2 How to Think About the Properties of Materials

The previous section considered how to conceptualise materials and their constitution. I conceptualised materials as made in their relations to social and technical arrangements and other objects and materials, as well as shaping these relations. In this section I consider how to think about the properties of materials, drawing particularly on Callon, Méadel and Rabeharisoa (2002) and Callon and Muniesa (2005). These studies, combining the sociology of marketing with STS, provide an understanding of how properties are defined and things come to have their value in the market place. Arguably, the making of materials is also about defining what can be done with them, the value to be given to the agency that in turn defines the identity of the materials.

With respect to the conceptualisation of materials in the previous section, I propose to think about the properties of materials as also constructed in their relations. Akrich’s (1992:205) explanation in her study of the making of the fluorescent light bulb within socio-technical arrangements of electricity infrastructure, particularly government and lighting installation utilities, guides my conceptualisation of properties of materials:

> The strength of the materials used to build cars is a function of predictions about the stresses they will have to bear. These are in turn linked to the speed of the car, which is itself the product of a complex compromise between engine performance, legislation, law enforcement, and the values ascribed to different kinds of behaviour. As a consequence, insurance experts, police, passers-by can use the condition of the bodywork of a car to judge the extent to which it has been used in ways that conform to the norms it represents.

This quote suggests that the properties of materials are enacted in relation to social and technical arrangements in which materials find a place. According to Callon et al. (2002) properties are 'revealed' in interactions with different actors and are modified as the product develops and changes in different environments. Callon and Muniesa (2005:1229) conceptualise this as 'calculation' in reference to the varied processes through which agreements can be reached on the value of products in the complicated market environment of ambiguous situations and conflicting interests. Goods are calculated differently in different arrangements, where properties and values given to them are defined by the groups involved in calculation, the technical capacities of the tools of measurement, and of course by the capacities of the goods themselves.

In their historical account of chemistry Bensaude-Vincent and Stengers (1996:254) state that 'the temptation to identify matter with what physical laws propose about it is as old as these laws.' I draw on ideas of Callon and his colleagues (Callon et al., 2002; Callon and Muniesa,

2005) to elaborate on this point in more concrete terms based on their study of markets. According to Callon et al. (2002:199) ‘a good is defined by the qualities attributed to it during qualification trials’ where qualification is defined as the ‘processes through which qualities are attributed, stabilised, objectified and arranged.’ They say that ‘the product is a strategic variable for the different economic agents engaged in the process of its successive qualifications-requalifications’ (Callon et al. 2002: 199). According to Callon et al. (2002:194), ‘qualifying products and positioning goods are major concerns for agents evolving within the economy of qualities’ and that these ‘agents’ ‘devote a large share of their resources to positioning their products.’ This is common concern for any makers of goods and services, and as well as for the makers of bioplastics.

Such a conceptualisation suggests that these agents are actively involved in the making of a product’s properties. So the processes through which value gets attached to things are shaped through the interests of agents who are doing the positioning. At the same time, the quotation above points to the fact that the agents who are doing the qualification are themselves affected by the results of their qualification work. Although Callon et al. tend to overlook the specificity of the good in question, their ideas of how things come to have their value are useful for my analysis of bioplastics, as a group of materials taken up differently by different actors. Thus, next to seeing materials as made in their relations I start to see their properties as made as well, as part of this making. I view the properties of materials as revealed in their arrangements, and as governed by agents who have varying relationships to them.

In the STS literature there are good examples of how concepts of calculation can be put to use to understand the value of a certain material as it circulates in different worlds. I draw on

Hawkins (2013a) to elaborate further on calculation and the properties of materials. Hawkins (2013a) studies the economic values of plastics, in particular the disposability quality of polyethylene terephthalate (PET), a type of oil based plastics invented around the 1940s. She sees properties and hence materials as made in their relations; in different arrangements, by different actors: so PET's economic values had to be 'elaborated and produced' (2013a:49). However, for Hawkins (2013a:49) this does not mean that materials are simply socially constructed; rather, 'the economic capacities of plastic emerge in specific arrangements and processes, in which material interacts with any number of other devices – human and non-human – to become valuable.' Hawkins' study of PET bottles utilises the concept of calculation to examine the qualification of PET as disposable, whereas PET in other contexts is a durable, tough and resistant material. Hawkins (2013a:51) examines the ways in which a particular quality, the disposability of PET in the form of bottle, is differently calculated and demonstrates that disposability is continually 'requalified in the different arrangements and economies in which it is caught up,' and that it is framed as both a positive and a negative quality.

Hawkins' (2013a:50) analysis shows that properties of goods 'are never fixed; instead they are continually being enacted in multiple networks and interactions.' Hawkins' explorations are inspiring for my study, in terms of considering different registers of 'bio' in different settings. However, studying bioplastics presents a challenge in that bioplastics comprise of a variety of materials. So, the category bioplastics actually refers to differently calculable products. Moreover, in the context of my own work, the implication is that each stakeholder – materials producers, converters, brands, end users, end of life processors – has a different relation to bioplastics, through which properties of bioplastics are produced, reproduced and made visible. The sociology of marketing and STS literature allows me to consider the making and positioning of bioplastics. Other materials would also need to be positioned, qualified, tested and developed in a similar fashion, however there are specific constellations of interests that gather around bioplastics that form and come from the specific character of the materials.

Callon and Muniesa (2005:1234) state that 'the properties that define the good as singular and constitute its profile or identity are neither intrinsic nor extrinsic.' This reinforces the conceptualisation of materials drawn in the previous section. They have tendencies and capacities, but these tendencies are also externally articulated, insofar as these properties are dependent both on test procedures, where a material is put in relation to the materiality of existing test equipment with a numerical output concerned with one particular material characteristic, and on the 'broader arrangements' in which the material is to find its place.

Callon and Muniesa (2005:1231) observe that the first step in calculation is to create a distinction between goods: 'calculation starts by establishing distinctions between things or states of the world, and by imagining and estimating courses of action associated with those things or with those states as well as their consequences.' What they refer to as 'detachment' defines a process whereby things are classified and compared on a common ground and distinctions are pointed out. For Callon et al. (2002:198) a good is 'defined by a combination of characteristics that establish its singularity.' After the singularity of the good is established, goods are associated with one another and compared by being manipulated and transformed. Callon et al. point to the comparative aspect of defining value, in that the new good must be positioned in relation to existing goods in terms of what it can do differently and in relation to the envisioned benefits of this distinction. As a result a new entity must be formed, which can circulate out of the common background and that links the new relations formed around it.

I adopt the terminology of Callon et al. (2002) to capture the dynamic nature of properties and the inseparability of qualities and the processes through which they are differently valued. Callon et al. (2002) prefer the term 'qualities' rather than 'characteristics' or 'properties.' According to their detailed analysis of properties of goods, the term 'characteristics' suggests stable properties, whereas properties are ever changing, in processes of 'qualification-requalification.' So I use 'qualities' from now on to capture the dynamic nature of value of properties as conceptualised by Callon and Muniesa (2005) and Callon et al. (2002).

From this vantage point, I analyse bioplastics and their qualities as an extension of such an effort to make goods distinct as well as singular. The making of a material starts with defining the material; defining it as singular and distinct and defining what can be done with it – its properties. This approach helps me to situate bioplastics – which are different materials that are categorised as bioplastics.

I also realise that, on the one hand, there are specific qualities such as permeability, or heat resistance, that are 'revealed' in various arrangements in which bioplastics are caught up. On the other hand, some of these qualities, such as biobased and biodegradable, form larger groupings that both bring these qualities more prominently into the field and also gather distinct materials under one category. The much discussed qualities of bioplastics as biodegradable – that they decompose in the earth – and biobased – that they are made of plant sources – reveal the fluidity of meanings, where these qualities appear to be relative and temporal. The first examples of oil based plastics were successful because they were durable and resistant to chemicals and grease. However, biodegradable bioplastics are made calculable and valuable in certain situations precisely because they decay. Biodegradability, which actually means that an entity cannot hold its molecular structure against microorganisms and external factors, is rendered as valuable in the case of some bioplastics, through re-calculation within a composting infrastructure and an environmental discourse. Likewise the source of biobased bioplastics, for example corn – a plant source – is valued as biobased in the context of plastic for Cargill,[9] while the very same corn does not have such values in other markets of Cargill in which it circulates. The same corn source is not valuable because it is biobased in the sweetener industry, as one example. Thus, a certain good can be calculated differently in different arrangements that makes up its identity.

2.3 The Relationship between Materials and Products

In this section I add to the above conceptualisation about materials and their qualities, seeking to form an initial conceptualisation of the relationship between materials and products that will help me to explore and unfold those relationships in my empirical research. As I mentioned earlier, except for the two studies that I identified – Schatzberg's (2003) article and Shove et al.'s (2007) book chapter – the relationships between materials and products are not generally studied in the sense I am taking them in my research.

Cultural and social histories, although they are specifically focused on a particular type of material, for example plastic, or more specifically Celluloid, a type of plastic, are mostly indifferent to the relationship between materials and products, and take the concepts materials, products and material-product as interchangeable (see Handley (1999) as an

---

[9] Cargill is the world's largest privately-owned corporation, based in Minnesota, US. Founded in 1865, they 'provide food, agricultural risk management, financial, and industrial products and services around the globe.' Information accessed from Cargill website: http://www.cargill.com/company/history/index.jsp on 5th Feb 2015.

exception, where she extends on the case of nylon stockings in the formation of an identity for nylon as a material). STS, similarly, by treating materials as technologies, and thereby seeing materials already as the object, miss the interface between materials and products.

In the design literature, in the last decade, materials have become the focus of interest of some scholars (Ashby and Johnson, 2002; Karana et al., 2008, 2009, 2012; Pedgley, 2009). These scholars have emphasised materials as a *dimension* of users' interaction with products. However, their focus is not on the relationship between the materials and the products. From their perspective, materials are simply 'chosen' by designers to address and invoke necessary emotions and interactions with products. Clearly, from this perspective materials are not conceptualised as I have described them, nor does this approach address how products and materials might constitute one another.

Material culture approaches, in contrast, seem to regard products as 'hindering' the human relationship to materials (Ingold, 2007a). I refer to the studies in the special issue of *Archaeological Dialogues* that I have mentioned in the introduction. In these studies, although scholars are in dispute on what to name as a 'material' and how cultural a material is, and so on how to study materials, there seems to be a consensus on the fact that products obstruct the apprehension of materials. For example, Ingold (2007a) holds the idea that the fact that materials are always in a product form hinder the material-ness of the materials to be experienced, in that only when a porcelain vase breaks or stucco crumbles we 'feel' the materials. He observes a tension in the relationship between materials and products where 'materials always and inevitably win out over materiality' (Ingold, 2007a:10).

With these critiques in mind I turn to the two useful studies that will guide my initial conceptualisation of this relationship. The first is the business historical account of aluminium by Schatzberg (2003), the second the book chapter of Shove et al. (2007:96) looking at plastics with the aim of focusing on 'the matter of material culture.'

Schatzberg (2003), in his business historical account of aluminium, portrays the different and changing symbolic meanings of aluminium in different sectors, and so in different product domains, such as in aeroplanes and electric wiring. He explores the different symbolic meanings that a material obtains as it comes into relation with different product domains and corporate bodies. And he argues that these representations and aspirations propel the investment and research into aluminium.

An important point that Schatzberg's study exposes is the controversial relationship between the generic aspirations of aluminium as the material of the future, and the physical capabilities of aluminium. He explains the comparison between aluminium and wood in terms of their buckling qualities, which is a critical quality for the material of which an airplane frame is to be made so that the frame can endure the extreme pressures during flight. However, as Schatzberg explains, due to its associations as the material of the future, aluminium was found to be more suitable for airplanes, although aluminium's buckling properties were found to be worse than wood. He explains this situation with reference to the symbolic meanings of aluminium, where as a modern material aluminium was found more appropriate for the building of the future of transport: airplanes. He suggests that qualities shift in value and capacities of materials do not necessarily result in employing that material in a particular product, as different qualities are made more salient within certain investment priorities and symbolic values.

I want to refer to Shove et al. (2007:96) here, as their conceptualisation of materials, specifically of plastics in their case, 'as a synthetic combination of molecules and social-symbolic reference points' summarises the points made by Schatzberg (2003) concisely. This suggests that the processes through which a material gets made as well as the processes through which a product gets made of a material, which might be conventionally thought to be a simply technical process, is actually both social and technical. However, as Schatzberg's (2003) study reveals, this process appears to be rather 'random,' and not an underlying, pre-established logic at work.

The study by Shove et al. (2007) provides the most encompassing guide for my research that focuses on the interface between materials and products. To begin, Shove et al. (2007:98) conceptualise the relationship between materials and products as 'co-constitutive and dynamic.' To briefly summarise their analysis, they start by expanding on the idea of Schatzberg (2003), who argues that symbolic values propel technological development. Shove et al. conceptualise this as 'promise requirement cycles' where initial expectations – the benefits in terms of qualities of materials – are set high and then guide research and development of materials. Shove et al. (2007:101) expand on this by stating that the 'specific instances of materialization are cumulatively significant for the redefinition and ongoing transformation of generic material identities', i.e. the specific products into which materials are made are important in shaping the generic identities of materials.

According to Shove et al. (2007:102) qualities of materials are made in relation to performance conventions of the products into which they are made, in that new materials 'modify concepts of performance associated with familiar and established objects' and 'provide focus for fresh product-specific interpretations of value and quality.' They give the example of the Parkesine comb,[10] where Shove et al. realise, firstly, that to communicate the qualities of this new material a product was needed. Secondly, the comb in return defined the valuable properties of Parkesine, as well as positioning Parkesine among other materials of which combs used to be made, such as tortoise shell or bone, thereby exemplifying how materials and products make each other. Moreover, Shove et al. (2007:102) recognise that Parkesine has 'multiple co-existing incarnations' as other types of products, such as medallion, card case or pen, thereby multiplying the qualities and identities of Parkesine. This also creates 'completely new terms of comparison, value and exchange' for the product as well as the material (Shove et al., 2007:107. For example, they give the example of polythene washing-up bowls, where washing up became 'quiet' (compared to the enamel washing up bowl that caused a noisy clatter in scratching plates against the enamel washing-up bowl).

Shove et al.'s (2007:114) analysis of historical sources of plastics demonstrates 'the co-evolving relationships between substances and objects.' To summarise the work of Shove et al. (2007:114) in their own words:

> In short, what materials 'are' and how they are seen depends, in large part, on exactly what they are made into. This relation is complicated by that fact that many items can be made of the same material, that materials are typically combined to produce specific artefacts and that new materials or composites make new products possible.

[10] Parkesine is one of the first plastic materials, and combs were one of the first products to be made of plastics by substituting for ivory and tortoise shell.

Shove et al.'s account demonstrates how qualities of materials are defined in relation to products, as qualities and identities of products are defined in return. Moreover, their account shows that this is a dynamic and ongoing process, given that materials are made into numerous products and new values and material taxonomies are produced and reproduced.

The conceptualisation that I develop here, adopting the co-constitution and co-evolution idea of Shove et al., provides a dynamic and flexible understanding through which to grasp the fluid field of bioplastics. This framework enables me to see bioplastics in their co-constitutive and co-evolving relations as well as in their multiple relationships to both products and other materials. I pose some questions that this conceptualisation allows me to attend to: How do materials shape products? What are the ways in which products shape materials? How do materials compare to each other, which essentially positions them and defines their identity? How do material-product relationships influence other materials, products, and material-products? How do these relationships evolve within the human and non-human environments and practices that gave rise to them? These diverse but also interconnected questions require me to develop a methodological strategy to effectively address the relationships in the field. This is the topic that I turn to in the next section.

2.4 Studying Materials: Strategies to Analyse Bioplastics

In this section, I proceed to explain the methodological strategies I developed in accordance with the theoretical conceptualisation of materials and material-product relationships explained so far in this chapter. STS, social histories of materials, and material culture studies have different focuses and so different conceptualisations and methodologies to explore the makeup of the world. My approach falls within the disciplinary interest of these fields, and so requires me to develop the strategies that allow me to address the making of materials and material-product relationships.

Scholars who have studied materials from the broad range of approaches mentioned so far from STS and social histories of materials, have used historical data, and current or past representations of materials on commercials and advertisements, to explore the actors that come into relation with a particular material and the meanings it has for the markets in which it circulates (Handley, 1999; Katz, 1978; Misa, 1995; Meikle 1997a; Schatzberg, 2003; Wahlberg, 1999, and more recently Hawkins, 2013a; Marres, 2008, 2014). However, for bioplastics which is a recent field that is rapidly in the making, I am not able to make use of retrospective historical accounts or to see the values created and their breakthrough effects in related industries and socio-material organisations. And the representations in current advertisements do not allow me to uncover either the relationships involved in making bioplastics, or the interaction between materials and products.

Material culture studies have a tradition of following objects themselves. Appadurai (1986:5), in *The Social Life of Things,* suggests:

> …we have to follow the things themselves, for their meanings are inscribed in their forms, their uses, their trajectories. […] Thus, even though from a theoretical point of view human actors encode things with significance, from a methodological point of view it is the things-in-motion that illuminate their human and social context.

However, following the 'bioplastic materials' in my case would suggest that the meanings are inscribed in the matter itself, and matter is a passive element in whatever meanings humans attribute to it. Such a suggestion would contradict my conceptualisation of materials as enacted in their arrangements and as active agents shaping those same arrangements.

Miller (2007:24) states that properties of materials are ‘dynamic processes constantly being shifted for a wide range of reasons,’ and methodologically he focuses on ‘the processes’ where materials and human beings are constituted in relation. Similarly I choose to look at the *processes* in which materials are mutually constituted with their human and non-human environments. More specifically, I focus on the processes of substituting materials and making material qualities visible. These on the one hand figure as strategies used by the makers of the materials to articulate and position materials and form material-product relationships. On the other hand following these practices provide me a useful methodological strategy that enable me to enter the field and capture the relations constitutive of bioplastics, as well as to go into details of their making and relationship to products. In what follows I explain how these processes are constitutive of bioplastics, and the ways in which they open up the relative and dynamic nature of making of bioplastics.

2.4.1 Conceptualising Substitution

Manzini (1986:60), in his book *Material of Invention,* which explores many aspects of materials in daily lives and in interaction with human agents, states that the first phase of ‘the introduction of a new material into a field of applications’ is ‘substitution and imitation.’ This suggestion seems reasonable for me to take as a starting point. My empirical data also reveal that substitution is a route by which materials producers introduce new materials. Paul Mines, CEO of Biome, and a member of Management Board of Lignocellulosic Biorefinery Network[11] explains that substitution of a material is usually realised through replacing one material with another in an existing product:

> *I am trying to think of an exception where someone had come to us and wanted to launch a completely new product, but I can't think of one. Most of them already have a product running in oil based plastic and then want to change it.*

Based on historical accounts of plastics and my empirical data, I contend that 'substituting', i.e., replacing one material with another, is one of the main routes through which bioplastics are realised in the market as products.

But here I want to expand on my conceptualisation of 'substituting' as not only a technical process comprised of simply replacing one material with another, but also a methodological tool that opens a window into the social and technical relations that inform the making of a material.

First of all, there are different processes and relations implicated in replacing one material with another. For example, substituting PS[12] with PLA[13] shopping bags seems to stand for a single instance of substituting, that of using PLA instead of PS, where PLA and PS are

[11] This quote is derived from my interview with Paul Mines, during the summer of 2014.

[12] PS (Polystyrene) is a traditional plastic of which bags are commonly made.

[13] PLA (Polylactic Acid) is a type of bioplastic.

compared on how well they bring the groceries home, how strong the bag is. But this one instance of substitution also involves production and means that PLA instead of PS will be processed in the production equipment. Moreover, sourcing and synthesizing will be different than PS, as PLA is sourced from plants instead of oil. The disposal as well is different, as the PLA bag will go to the compost heap or to the composting facility. So one instance of substitution will have implications for the whole production and disposal chain, as well as for how the product is positioned, calculated and qualified.

Arguably, each of these ‘instances’ stand for different worlds, where different actors, with different interests, come into relation with bioplastics. For example, there are various processors involved in the production of a PS or PLA bag, such as granule producers, blown film extrusion specialists, printers, stretch-blow-moulders, and another production assembly for sealing and cutting the handles of the bags. In addition there will be different actors and groups at the composting end, such as waste management companies, composting or incineration facilities. In these different worlds bioplastics have to be positioned by comparing them with the previous and alternative materials and social and technical arrangements, so as to define their value.

Secondly, following this, substituting is part of the making and defining of bioplastics in terms of the dynamic of establishing and valuing materials in and through complex relations between different groups – human and non-human – within the specificity of the production chain. It defines technical and social processes in which some aspects of the materials become relevant, valued, made visible and reproduced, and materials are positioned in relation to each other, and in relation to specific products. In a way, the processes of substitution define the identity of the materials, in terms of what they are and can be. It is important to note though that the relationships between these different worlds do not define linear patterns, as are commonly attributed to physical production.

Substituting involves multiple, social and technical processes, in and through which materials are qualified in that they are compared to other materials and are evaluated within the human and non-human arrangements that they become part of. As such, substitution is a generative process, where new values and materialisations are produced and reproduced.

Thus, following bioplastics into different instances of substituting offers methodological advantages. First, it allows me to enter the field composed of fluid relations, for which neither a beginning nor an end can be determined. Since I am building my analysis on an argument in which materials and properties are made in their relations, exploring substitution enables me to fix the relations temporarily, for that particular instance of substitution.

Secondly, studying instances of substituting helps me to bracket the instances of complex and interconnected production processes, and temporarily stabilises relations, comparisons and values. Attending to an instance of substitution, I get a glimpse of the values compared and the actors involved. So focusing on one 'instance' of substitution, such as substitution in product, substitution in disposal, or substitution in production, allows me to bracket that instance from the whole process and examine the dynamics for that particular instance, where material specificity, different interests and relation of actors are redefined and temporarily fixed. This enables me to consider the processes, values and relations through which bioplastics and their qualities are articulated in and through the relationships with human and non-human actors.

Thirdly, following bioplastics into different instances of substituting allows me to explore the technologies that went before bioplastics and social and technical arrangements in which bioplastic materials are situated. Fourthly, it lets me access co-existing materials or other products. From here, I can obtain a more detailed account of closely-coupled relations between materials and products and acquire data on specifics of making.

Finally, following substituting is a strategy that lets me investigate the interface between materials and products, in that I can see materials as separate yet interrelated with products, and consider their making into products and the qualities and terms of evaluation that become relevant in specific arrangements of bioplastics, products, and other materials.

2.4.2 Conceptualising Processes of Making Visible (and Invisible)

Another practice I focus on is 'visibility.' This might sound trivial and uninteresting. However, I will argue that 'making visible' is a strategy that different actors use to negotiate the value of materials. It is charged with the different interests of differently related actors. As such, unfolding the 'visible' is a methodological strategy that reveals the stakes around the making of bioplastics; the important qualities, issues, and discussions that inform the field of bioplastics.

I elaborate on 'making visible' as a strategy that actors use to articulate certain qualities and negotiate the value of bioplastics first by making use of my interview data. Marc Verbruggen, the CEO of NatureWorks, the largest bioplastic producer globally, mentions, without giving a specific example, how NatureWorks sees 'making visible' as an integral process to how their company works, and one that is refined through long lasting relations in the field:

…what we learned over time is how to fine-tune your message [meaning what to make visible and how], how to fine-tune your value sale, depending on the application, and depending on the region of the world.[14]

Verbruggen's explanation shows how NatureWorks adjust their message to address particular values of certain sectors and regions. They make different qualities visible to different actors, in different arrangements, so as to negotiate – to fix and to challenge – the identities and qualities of materials, and to position themselves in relation to other materials. I conclude that in the making of materials, different qualities are made visible and relevant by materials producers or brands in different instances of substitution for different actors. Visibility is in this respect, a way in which qualities are articulated and negotiated. On the one hand, visibility shows me what the actors involved in the making try to do and for whom, and what counts. On the other hand, it shows me what is made 'invisible' and irrelevant, thus excluded from the field and positioning of bioplastics.

I follow making qualities visible and invisible as the second methodological strategy that allows me access to the field, in terms of qualities that are valued and the stakes around articulating these qualities. I look at what is made visible and prominent regarding bioplastics in the sources I scan and by my respondents. While it is easy to see what is made visible, my task is to look at the stakes around the visibility of bioplastics, and what is made visible, by whom and for whom, and why.

---

[14] Quotation derived from my interview with Marc Verbruggen on 28th May 2014.

2.5 How Do These Approaches Direct My Study?

In this chapter I have set out a theoretical and methodological framework that allows me to explore the complex relationships in which bioplastics are situated. This conceptual framework encourages me to avoid taking materials and their properties for granted, allowing me to consider how they are made through their relationships to products, industries and interested parties and in various arrangements, and to see their values as *articulated* in their relations. The relationship between materials and products is multiple and dynamic, where materials and products continuously co-evolve.

In the next chapter I will elaborate on my empirical sources, before I move on to my analysis of the empirical material. The first empirical chapter, Chapter 4, analyses the category of bioplastics and tackles the questions that I posed in the introduction regarding how bioplastics were defined and what is qualified as ‘bioplastics’, which materials are included and not included in the field. I see this as an issue of categorisation and grouping of qualities, where the qualities biobased and biodegradable have become prominent and visible groupings of bioplastic materials.

One issue in the rapidly emerging field of bioplastics is what to name as bioplastics; how to define bioplastics and which materials are included and not included in the field. So Chapter 4 looks at the work of definition, focusing on categorisation as both a consequence and facilitator of defining and creating a new material. More specifically, I examine categories of bioplastics by looking at what is made visible in the field, mainly as it is reflected in *Bioplastics Magazine* and through my interviews with the spokespersons of certain companies. Looking at what is made visible and prominent in the field reveals the issues that count, stakes around these issues, different interests of actors and their varying influence on the making of bioplastics.

At the same time, I realise that materials are also made through their specific production relations, as they become part of daily life and practices. Chapter 5 goes into the specifics of the physical making of materials by materials producers, and looks at the specific qualities of particular bioplastics. I explore indicative bioplastic examples, such as PLA bottle and packaging, and how PLA substitute for other materials. I look at the processes of substitution according to my conceptualisation of substitution as a generative process; the dynamics of substituting bioplastics and the different interests of the companies involved are central to the making of materials into products. I focus on the instances where bioplastics are substituted for and compared to other materials in certain products and production stages, to explore the issues with articulation, positioning and valuing qualities of bioplastics. The qualities rendered valuable and made visible inform research and development activity, and in that way the future of bioplastics' development. I explore the specific relations through which bioplastics are turned into products, within particular exemplary cases. Substitution actually affords a much more nuanced account of the making of a material in its specific arrangements.

In the last empirical chapter, Chapter 6, I explore visibility more closely. Visibility, both as a strategic tool for makers of bioplastics and a main route through which the identity of bioplastics is negotiated, is a central issue throughout the thesis. Here, I distinguish between different forms of visibility and consider its implications in terms of the relationships between materials and products. I explore the advantages of rendering bioplastics visible in product form, e.g. through labels or other markers, and how this material is positioned because of its bio aspects, by means of exploring a selection of products in which the bio property takes on a salient form.

CHAPTER 3

THE MULTIPLICITY OF BIOPLASTICS AND EMPIRICAL SOURCES

In the previous chapter I explained my theoretical framing of materials, wherein materials are conceptualised as made in their relations, and materials and products as co-constituted. Accordingly, I offered the processes of 'substituting' and 'making visible' as the methodological strategies that allow me to access this dynamic field.

In this chapter I turn to an exploration of the empirical field, in relation to which I choose a particular set of actors as my empirical focus. Building on the broader picture of bioplastics demonstrated in the first introductory chapter, in this chapter I focus on the production and supply chain relationships of bioplastics that I consider to be the empirical site in which the materials are *transformed* into products. It is the most useful to describe my research process as composed of two parts. The first exploratory part (Section 3.1) comprises a thorough search of commercial bioplastic products along their supply chain, by means of online searches, planned interviews and opportunistic enquiries. I present a story of the supply chain of bioplastics and describe the multiplicity of bioplastics – the different worlds of which bioplastics are a part. Although I do not directly refer to these explorations in my analytic chapters, they helped me to get a better picture of the field, as well as to make a feasible research plan in terms of the sources of information, access and time span. I believe it is also useful for the reader of this thesis to get to know about bioplastics through my account of the supply chain, in order to situate my research and its empirical focus better.

The second part of my research (Section 3.2) comprises the main empirical focus that informed the analysis in my thesis, and I expand on the key actors that I identified, as well as how I collected and analysed data (Section 3.3 and 3.4). Acknowledging there are other ways of studying the field of bioplastics, this chapter also addresses the limitations of my method (Section 3.5).

3.1 Exploring the Field: The Multiplicity of Bioplastics

Since as ordinary consumers we encounter bioplastics only in product form in our daily lives, I started exploring the range of bioplastic products and their relationships by investigating shops and retailers (in the UK, Turkey and the Netherlands), visiting a trade fair, conducting interviews and making opportunistic enquiries, as well as by examining secondary sources such as online news reports and related websites. These explorations led to an extensive account of the multiplicity of bioplastics, which I explain in a retrospective story below, specifically with the objective of situating my empirical focus better.

It is important to state that attending to the ‘multiplicity’ of a phenomenon has methodological significance within STS. Woolgar and Leazun (2013) discuss a ‘turn to ontology’ in STS within the theoretical conceptualisation of the ‘enactment’ of objects. They state that ‘objects are brought into being, they are *realised* in the course of a certain practical activity, and when that happens, they crystalize, provisionally, a particular reality, they invoke the temporary action of a set of circumstances’ (Woolgar and Leazun, 2013:323-4). Hence, my ontology aims to move away from the representations or knowledge of a reality, towards the multiple realities in which objects are enacted differently – their multiple worlds.

These explorations should also be seen as part of navigating in an alien field that is recently in the making, dynamic and opportunistic. Bijker (1995:13) in his account of the social and technological change of bicycles, Bakelite and light bulbs, sees technical change as 'a process of trial and error, as a cumulative result of small and mostly random modifications' as opposed to having a 'goal-oriented' or intrinsic character. Moreover, if bioplastics were an established and relatively stabilized field, like plastics for example, I would be able to take an historical account of bioplastics as my starting project, (as Bijker, 1995; Meikle, 1997a; and Misa, 1995 in their accounts of different materials were able to do), and would be able to situate my current interest within the established social practices and networks of relations in and through which bioplastics came to be. However, bioplastics are currently in the making with a very short span of history.

I admit that I went down some cul-de-sacs that initially looked promising, or the significance of a topic or an actor was brought to a new, less significant status as I kept integrating new data. Initially, in this exploratory part, I conducted 12 semi-structured interviews with personnel of shops and retailers that sell and promote bioplastic products and some enquiries at the local shops and the annual trade fair for gift items that I visited. I literally *drew* a map myself with funny visuals, for drawing is my way of thinking as a designer (Appendix A). This map, however, should not be taken as an ambitious project or as an extensive topography of the field, as my intention is not to freeze the relations as such a map might suggest, and as claiming to have reached a complete and final map would essentially conflict with my conceptualisation of materials. This provisional map is just aimed at delineating the players, so as to provide a starting point for my research. I should also make the point in passing that if I would draw the map now – three years later – I would need to add many more companies producing bioplastic materials and products, many more different types of materials and products, which were not in circulation at that time, as well as many more players. The field is growing rapidly and even the Wikipedia page, which comprised a few paragraphs three years ago, now contains pages of information with links about different types of bioplastics, different qualities, and different products into which they are made.

A (Provisional) Map of the Field and the Multiplicity of Bioplastics

I start my account with the bioplastic products as I first found them: on display at shops to be sold. These products seem to be of three types. The first type is the product that is itself made of bioplastics such as pots, cups, or mobile phone casings. The second is the packaging that is made of bioplastics – so not the actual product to be sold but its protective cover, such as bioplastic bottles of Coca-Cola. And the third is the specialist products, which ordinary consumers do not encounter, such as, PLA filament for 3D-prototyping a bone scaffold. It was already clear that bioplastics were not made into one single type of product, nor were they a single material that was produced by a single set of actors.

Going 'down-stream' from the display at shops, these products are bought and used by consumers and are discarded at the end of their useful product lives, either trashed as general waste, or separated for home or industrial composting. As general waste, they are taken to landfill or incinerators, whereas in an industrial composting facility they become compost to be used in the agricultural sector. Although inevitably materials and products are qualified-requalified, using Callon et al.'s (2002) term, by the economic agents in these various arrangements, these agents are not the actual makers of bioplastics, or initiators of bioplastics' inclusion in these networks.

Therefore, going 'up-stream' in the supply chain seemed to be a more promising direction for the purposes of my research. I went on with the initial consideration that in the places where I found bioplastic products I would find complex dynamics at work – the small and large scale shops and retailers who chose these products to market through complex dynamics. I considered this a process through which materials come to be. I therefore conducted semi-structured interviews with a set of local shop owners and staff, as well as searching in the directions that they pointed me.

Local co-ops or speciality shops with a specific focus on environmentally friendly goods, which I will refer to as 'eco-shops,' tend to supply a range of bioplastic products, mainly in the form of packaging and compostable waste bags. These eco-shops supply a wide variety of goods, from cleaning products of global companies like Ecover, to food crops from local farmers. One shop in particular was a 'gift-shop' that supplies a collection of gift items without a specific orientation on the environment, Fair Trade or organic. In some large retail stores as well, it is possible to find bioplastic products, such as bioplastic packaging bottle of Ecover cleaning items. (In other countries, Turkey and the Netherlands, there seems to be a broader variety of bioplastic products either to be found in speciality stores or in regular retail chains.)

Although these eco-shops and gift-shop did have the products I was looking for, to my surprise the shop owners and staff, to whom I spoke, were not familiar with the bioplasticness of these products. They would react saying things like 'Ehm... Sorry... What are bioplastics?' or 'I honestly don't know anything about that!' I found that despite their unfamiliarity with the term bioplastic, they were more familiar with the qualities biodegradable, compostable, but less so with biobased. This observation brought to my attention that bioplastics and their different qualities are differently visible to different users of the products.

I learnt in my interviews that these shops mainly deal with the products that are made available to them through larger retailers by means of catalogues or various trade fairs, for their sales figures – for the eco-shops and the gift-shop that I visited – were not large enough to be supplied directly from the brands. From this perspective, the larger-scale distributors appear as more significant actors, and the trade fairs appear as a platform where these different groups come together. I went to one such trade fair, the International Autumn Fair,[15] which is a trade fair for gift items, so not specific to the materials; rather it is the products that are explicitly on display. However, the fair demonstrated the broader context where the role of these shops and retailers became clearer. I will, therefore, briefly recount my observations.

The trade fair was an event where the producers of products, and the large and small scale retailers, communicated, elaborated, and translated the qualities of products. Some of these qualities were explicitly about the materials of which products are made. This made me question the norms around materials and products. What was the boundary between a material and a product, and when was a material a core value of a product? What was the significance of these boundaries for the material-product relationship? Also, I came to realise that shops and retailers were not the actors who articulate a new quality or a value around bioplasticness, nor were they involved in the configuration of material-product relationships. Evidently, these actors merely took up the qualities already elaborated and mobilised in

---

[15] Autumn Fair was held in NEC Birmingham, 2-5 September 2013, where over 1600 exhibitors demonstrated over 60000 new products according to the website of the fair, www.autumnfair.com.

particular discourses and passed them on, or utilised them to enhance the identity of the shop/retailer. For example, I noticed a pattern in which retailers of all sizes and organisations with environmentally friendly positioning tended to supply various kinds of bioplastic end-products as these products matched with environmentally friendly positions. In this sense the retailers that I initially considered to be decision makers and to direct dynamics through which qualities of bioplastic materials are articulated comprised just another consumer of bioplastic end-products. As such, instead of the retailers or distributors, the actual makers of the products then, I concluded, make a more appropriate point of departure for my research, to which my account now turns.

'The makers of products,' as I refer to them, are companies such as Nestle, and Procter & Gamble, or small brands like Zuperzozial and Effektchange, that invest in or brand the end-products made of bioplastics. As part of branding and positioning their products these companies articulate various qualities of bioplasticness – either standardised or non-standardised – and actually create a bioplastic identity. The worlds that create bioplastics within these companies, and of which bioplastics effectively become a part, are varied. In some cases bioplastics find a place within corporate responsibility schemes, and in others they operate to enhance and elaborate on the values that the company stands for, or to create market advantage by making certain values upfront. In other cases, adopting bioplastics is a means to adhere to certain legislation, which points to the significance of the political interests in bioplastics and law enforcement. For example, as a result of coming from plant sources, bioplastics align with different regional politics, for example the agricultural development priorities in France. In these cases, other actors come into play such as governmental policy makers and sectoral interests. Standards bodies become involved to maintain and control the quality standards. As a consequence of these positioning, marketing and survival moves, bioplasticness is configured differently in these various worlds.

Bioplastic end-products are physically made in a set of transformations through ‘converters’, which transform bioplastic materials to end-products. Briefly, converters stand for the specialist producers that take the bioplastic beads (granules) or films and process them into products. For example, a plastic bag is produced through a stretch-blow moulding process, whereas a mobile phone case is produced through injection moulding. Converters are also multiple; they are part of different industries and work through different supply chains. Further details about the converters and production processes will be explained as they become relevant to the particular cases in the thesis.

Finally, the story comes to bioplastic materials that might be referred to as ‘raw materials’ in a common sense, to describe the granules that are processed and made into end-products. Bioplastic materials are synthesised as traditional oil-based plastics and manufactured into granules, as well. As mentioned, bioplastics do not refer to a single material, but a multitude of materials. Accordingly, bioplastics material producers are multiple as well. In my initial search for ‘materials producers’ I ended up, again, in some dead ends. I conducted an interview with a bio-chemist at Lancaster University, who I considered to be a maker of these materials. However, I observed that there seemed to be disconnect between the chemistry lab and the commercial products. The bio-chemist was neither familiar with the generic qualities of bioplastics, nor with the products into which they are made. She was merely focused on finding a new formulation that enhances heat resistance of bioplastics, in particular PLA (as bioplastics are found to have inferior heat characteristics compared to traditional plastics). I quickly concluded that the industrial producers of bioplastics were the kind of materials producers I was looking for, i.e. those who *physically* make a material and substitute it – hence compare it – with existing materials and *realise* it in commercial markets by elaborating certain qualities. In the next section I expand on the variety of 'materials producers', describe my analysis of the types of materials producers, and explain why I chose those particular materials producers.

I finish my story at the food crop suppliers, from which materials producers take the plant sources, and synthesise starch or cellulose to produce bioplastic materials. Here bioplastics are a part of the agricultural world (and not the petroleum industry of which traditional plastics are a part). I will elaborate on the relationship of bioplastics to agricultural production networks in the coming chapters. But here it is important to note that bioplastics are made through these series of transformations, whereby each subsequent producer is both a producer and a supplier seen from different perspectives.

Reflection on My Initial Explorations

This chapter so far has described my efforts to orient myself in the field of bioplastics, one that is rapidly in the making. It has also demonstrated the multiplicity of bioplastics; bioplastics are shaped in and through various production chains as well as in interaction with various social groups (NGOs, environmental and governmental organisations), sectors (agriculture, packaging), and production and legal infrastructures (particularly the socio-technical organisation of industrial production, standards, and certificates). This multiplicity should not be seen merely as a methodological tendency within the recent 'turn to ontology' in STS (for a discussion on ontology see, Woolgar and Leazun, 2013). Woolgar and Leazun (2013: 326) call for attention not to 'a plurality of world views, but (to) a plurality of worlds.' This nuance suggests that within the evident multiplicity of bioplastics I should find the different arrangements in and through which bioplastics come to be, rather than bioplastics as a single object seen from different perspectives.

This approach also cracks open the boundaries between materials and products. To give an example, materials producers refer to the material they have produced as their *product*. Similarly, 3D filament – the product of one company – is the material used in the rapid prototyping process to make other products. These examples show that the boundaries between a product and a material shifts along the supply chain. I attempt a conceptualisation of products as modes of transformation of a material, noting that these modes redefine the material and its relation to products in return.

I found that the landscape of the bioplastics industry is rather fragmented and fluid. This signalled that it would be challenging to address the field as a whole. Nor is there a leading thread within the industry to justify a single focus, or if there seems to be a focus it changes very quickly. For example, bioplastic water bottles were considered a promising application in the field where there were PLA bottle conferences held between the years 2004-2008, but then the interest into water bottles declined.[16] There could have been some methodological ease in focusing only on one type of bioplastic, such as PLA and the products it is made into, as the categories and qualities are constantly shifting. However, in a way, these constant iterations *are* making the field. Within this line of thinking the first thread of inquiry is roughly

[16] *Bioplastics Magazine*, 2006/2, 'First PLA bottle in Germany' by Michael Thielen. *Bioplastics Magazine*, 2007/1, 'The +1 Water™ "bio-bottle", a first in Canada', by Michael Thielen. *Bioplastics Magazine*, 2007/2 'Five PLA bottle pioneers', by Michael Thielen. *Bioplastics Magazine*, 2007/3 1st, 'PLA bottle conference 2008/6 PLA Bottles in US' by Michael Thielen.

shaped as: How do bioplastics come to be defined as they are? How are these categories made? Who makes them? For whom? And to what purpose?

The second thread of my thinking follows the question: How can I understand the disconnectedness between the lab and the commercial environment? The bio-chemist who I interviewed early on was interested in different things compared to the retailers and the consumers. Relatedly, the retailers of bioplastics were not familiar with bioplastics as such, but rather they were familiar with some of its qualities. Clearly, different actors have different interests in different aspects of bioplastics, through which what becomes prominent or valorised partly defines what bioplastics become.

3.2 Identifying the Key Makers of the Field

In this section I describe the key actors who I identified in order to collect data on the processes through which bioplastics are defined, substituted and made visible. In this main stage of my empirical research I conducted 22 additional interviews with the makers of materials and products. Before I move on, I want to clarify my usage of the term 'makers', as I do not want to suggest that the set of actors who I identified are the only significant actors making the materials. I acknowledge that the making of materials is done in very distinct places, and continues in the course of the everyday lives of ordinary consumers and in the environments of which bioplastics become a part. I use 'makers' in a more limited sense, to describe the physical making of bioplastics and products, where I narrow down my focus to those who are involved in the positioning and actual physical production of the materials and products. From those makers, I wanted to choose large scale players in the field. Large players are associated with market success and significant influence, as they lead the market with large volumes making bioplastics into a mass produced industrial material. I tried to interview spokespersons who are themselves active in the field through membership in various organisations, and so active in making the field with their (and their companies') points of view.

3.2.1 The Trade Magazine and Its Editor

The first source of information I identified was related to the work of 'defining.' The industry's work of framing a new set of materials as bioplastics and the related negotiations regarding its members, boundaries, and identity as a 'bio' type of plastic captured my attention as a major project in both making the field and uniting the diverse actors of the field. Accordingly, I identified the trade magazine, *Bioplastics Magazine,* as a key actor in making the 'category' bioplastics, as well as in constructing its identity. *Bioplastics Magazine* is a print magazine, first published in 2006, and it is the first and only international magazine devoted solely to bioplastics. The magazine handles bioplastics in general, i.e., it is not limited to a geographical region, application or specific type of bioplastics.

Trade magazines do more than simply promote products and producers. As Cochoy (2012:173), in his account of the making of the modern grocery industry, says, trade magazines have 'a narrative aimed at accounting for business evolutions while shaping them at the same time.' By means of introducing a business as a unified category in the first place, they actually *make* the category, as well as defining its identity and the related actors. In his extensive account of cultural history of traditional plastics, Meikle (1997a:99) makes a similar observation about the trade magazine *Plastics*, about which he states: 'Nothing so clearly announced the new field of 'plastics' as the first issue of the trade journal of that name in October 1925.' Firstly, he explains, the magazine – as a published source of information – and its editor united the fragmented industry that was composed of diverse materials, products (from children's toys to airplane windshields) and converters, joined under the quality of malleability, from which the name plastics came. Secondly, they promoted plastics and introduced plastics to new markets. Lastly, they directed the industry, where Meikle (1997a:101) goes as far to say 'more than a trade journal less than a trade association, *Modern Plastics* [at some point the name of the magazine was changed by adding Modern] functioned as both through much of the 1930s.'

Indeed, *Bioplastics Magazine* works in an unconstrained and independent collaboration with the European Bioplastics Association, which defines itself as 'the association representing the interest of Europe's thriving bioplastics' industry' where 'European Bioplastics is committed to ensuring a continuous development of this important sector by securing the necessary support from European policy-makers and other key third-party stakeholders.'[17] As can be inferred, the association and the magazine participate in the politics of bioplastic materials and arguably are influential players in the regional politics of bioplastics, regarding their production and on other related issues.

The editor of *Bioplastics Magazine* is also very active in the field. He organises special events within relevant trade fairs, such as a 'Bioplastics Business Breakfast' within the largest plastics trade fair, as well as conferences about specific topics related to applications or issues raised regarding bioplastics, such as the biannual PLA World Congress or conferences such as bio!PAC (for packaging) and bio!CAR (for automotive applications). In a way, these events

[17] Text accessed from European Bioplastics Association's website http://en.european-bioplastics.org/ on 13th Jul 2015.

bring different groups together and produce and reproduce the relationships shaping bioplastics, thereby actively *making* the field.

I interviewed the editor of *Bioplastics Magazine*, Michael Thielen. He provided valuable insight for my research as the person who has been there from the beginning and has been actively involved in the making of the category bioplastics. Thielen kindly provided access to all issues of the magazine published from 2006 to 2013 – 42 issues, each consisting about 50 pages – which was a vast source of information for me. The magazine keeping the heartbeat of the industry was both a direct information source for me, and also provided opportunities for analytic inferences regarding the nature of its content and the changes that it went through during the years. Both the magazine and my interview informed the discussion in Chapter 4 on making the category of bioplastics.

3.2.2 The Materials Producers

My second empirical focus is the materials producers, who make the materials to be named as bioplastics, and also substitute them for existing materials. As such they are the actors that realise bioplastic materials in commercial markets. In this section I describe the types of materials producers that I identified by researching websites of companies; more specifically, company mission statements, visions and advertisements.

Before I continue to elaborate on the specific materials producers, it is important to emphasise the rapid growth of the field once more. I identified these types of companies during 2013, and my categorisation might be different if I looked at the field in the future. Also I focused on the current actors. I excluded, for example Metabolix, which was one of the first materials producers, as they could not make it through the initial struggles of the field. Metabolix might have been an influential player in the overall history of bioplastics, however since bioplastics have a (hi)story of less than two decades, I would not yet be able to judge their relative place in the field.

Some of the companies in the field are what I will call the 'pioneers.' These are the first actors in the field that started as research and development projects of large companies, which later became independent companies. Not all of these were supported by the parent company, as they were abandoned in times of economic crisis. In addition to being one of the first, these companies are currently significant players in the field in terms of their volume of production, such as NatureWorks and Novamont. The materials of these companies are new material formulations as well, each trademarked with unique trade names.

Another type of materials producers is what I will name the 'opportunists.' Basically these companies, such as Braskem and DuPont, were attracted to the rapid growth of volume and interest in bioplastics as the plastic of the future. Not to be left out of the competition, these companies either launched a bioplastic portfolio next to their traditional plastics, or switched to bioplastics totally, or alternatively were founded to produce bioplastics. *Bioplastics Magazine* regards the materials produced by these companies under a different category, named as 'drop-ins', as these materials are just a new way of producing conventional plastics from bio-mass, as opposed to oil sources, so their formulation is the same as traditional plastics. Although these companies arguably comprise part of the industry in terms of volume in production, they are not influential the same way as the pioneers, for these companies act on the growing visibility of bioplastics, rather than being engaged in defining the industry of bioplastics or building the bioplastic identity. I was accordingly less interested in exploring the role that these companies play in the making of bioplastics.

As I have mentioned before, bioplastics are essentially not a new type of materials in that the first plastics were actually what is now categorised as bioplastics. As we might expect, there are also ‘veteran’ materials producers that have persisted since the 1920s. Innovia Films, producing the ‘Cellophane’ of the 1910s, is one example. Clarifoil is another, similar materials producer that has persisted since the 1920s, with the same Clarifoil film material. Today, these companies are influential bioplastics producers. Due to their established industry lines, they have volume production in the sectors they have built over the past century. Innovia, especially, is an active player in the bioplastics field, working on a ‘bio’ identity and contributing to the formation of a bioplastics industry.

The last type of material makers I identified were the ‘new’ companies, which were founded after 2003-6, when the first commercial bioplastics were introduced and the initial struggles of the field were over. These companies mobilise their vision of better and cleaner production through certain qualities of bioplastics. This interest in contributing to the identity of bioplasticness separates these companies from the opportunists I mentioned above. These materials producers, such as Biome and Purac, are smaller in comparison to the influential pioneers, but have a unique positioning in the field with specific types of materials.

Next I will introduce my sample of companies by providing brief company biographies and details on the bioplastic materials they produce, and situating them within the categorisation that I just set out. In some cases, my contact persons in these companies were also influential members of the field, due to their role in key organisations. In those cases I specifically mention these spokespersons as well, and give details of their positions.

NatureWorks

NatureWorks is 'the first to offer a family of commercially available biopolymers derived from 100 percent annually renewable resources,'[18] making them 'pioneers' of bioplastic field according to my categorisation of materials producers. NatureWorks is also the largest bioplastics producer globally, with annual production of 160,000 tonnes,[19] which makes it similar in size to a conventional plastics production plant. This number equals 90% of the PLA market, and almost half of the bioplastics market, when drop-ins are included as well (some sources do not include drop-ins within the category of bioplastics).[20] NatureWorks was started in 1989,[21] as a research and development function of Cargill,[22] a large scale corn producer in the Northwest of US, 'to find additional uses for corn as a feedstock.'[23] Their material, trademarked as Ingeo® in 2003, is a PLA which is a new type of bioplastics. And Ingeo stands for a range of materials with different qualities that are sourced from corn and are either compostable or durable. I spoke to the CEO of the company, Marc Verbruggen.

---

[18] Accessed from http://www.natureworksllc.com/About-NatureWorks on 25th Feb 2015.

[19] Production capacity for 2009 Accessed from http://www.natureworksllc.com/~/media/News_and_Events /NatureWorks_TheIngeoJourney_pdf.pdf on 18th May 2014.

[20] Information derived from my interview with Marc Verbruggen on 28th May 2014.

[21] Accessed from Website of NatureWorks http://www.natureworksllc.com/About-NatureWorks on 25th Feb 2015.

[22] Cargill is the world's largest privately-owned corporation. Founded in 1865, they 'provide food, agricultural risk management, financial, and industrial products and services around the globe.' http://www.cargill.com/company/history/index.jsp on 5th Feb 2015.

[23] Quotation derived from my interview with Mark Verbruggen on 28th May 2014.

Novamont

Novamont is also one of the 'pioneers', as one of the first companies in the bioplastics field, founded in 1989 'with a view […] to integrate chemistry, agriculture and the environment.'[24] Based in Italy, Novamont, as Francesco Degli Innocenti, Director of the group for Ecology of Products and Environmental Communication explains, 'had to stand on their own feet' from the very beginning. Novamont has tried to form legislative support for bioplastics and it functions in close proximity with government bodies and municipalities. In addition, it is listed as a supporting member of European Bioplastics Association. Today Novamont, as represented on their website is 'one of the most important companies at a world level producing biodegradable and compostable bioplastics. Definitely one in the forefront.'[25] This is a view that I hold of the company as well, based on its influence in the field as reflected in reports about it and its presence in *Bioplastics Magazine*. Novamont's materials are trademarked as Mater-Bi® and sell about 60,000 tonnes a year.[26] The range of materials that Mater-Bi® stands for are currently derived from starch, cellulose, vegetable oils or their combination, and are compostable.

---

[24] Accessed from http://www.novamont.com/Profile/default.asp?id=463 on 25th Feb 2015.

[25] Accessed from http://www.novamont.com/Philosophy/default.asp?id=2060 on 25th Feb 2015.

[26] Information about sales figures derived from my interview with Francesco Degli Innocenti on 12th May 2015.

Innovia and Andy Sweetman, Chairman of Key Associations

It would not be wrong to say that Innovia Films is one of the oldest companies in the overall plastics industry. The company started in the 1930s, in the UK, utilising cellulose viscose technology developed in 1892, 'when three English chemists, Charles Cross, Edward Bevan and Clayton Beadle, discovered how to manufacture cellulose viscose', a material which was then modified into Cellulose film and patented as Cellophane in 1912.[27] Since then the company has been handed over a number of times and changed names, lastly in 2004 it came to be known as Innovia Films.

Innovia produces both conventional plastics and bioplastics. They have been producing Cellophane – which is today categorised as bioplastic – since the 1930s, as well as Biaxially Oriented Polypropylene, which is a type of traditional plastic. As a result of new standards and possible markets forming around compostability, in 2003 they developed a new material, something of an improved version of Cellophane, called NatureFlex™.[28] 'NatureFlex™ films are cellulose based, derived from renewable wood-pulp and are certified to meet both the European EN13432 and American ASTM D6400 standards for compostable packaging.'[29]

---

[27] Accessed from http://www.innoviafilms.com/innovation-centre/Innovation-Timeline.aspx on 9th Feb 2015.

[28] Information derived from my interview with Andy Sweetman, the Global Marketing Manager at Innovia, on 26th June 2014.

[29] Accessed from http://www.innoviafilms.com/News---Events/Media-Centre/QUALITY-STREET%C2%AE-Wrappers-Go-Compostable-With-New-N.aspx on 9th Feb 2015.

Back in 2003, NatureFlex™ was 'the first biobased and compostable heat sealable cellulose film.'[30] They have a production capacity of 26,000 tonnes of Cellophane and NatureFlex™.[31]

With this background, it is possible to place Innovia differently than NatureWorks and Novamont. First of all, it was an existing multinational company, having industry relations with a diverse range of converters and end users. Their material is also different in that NatureFlex™ is already in film format and the material is sometimes the end product too; for example the transparent film material can be both cut and printed and sealed to become a packaging product, or it can be used as the lid (so already the product) to be sealed on packaging products. Lastly, the material has a defined application area, in that Innovia produces only for the packaging industry.

My contact person at Innovia was special as well. Andy Sweetman, who is the global marketing manager at Innovia, was also the chairman of the trade association European Bioplastics Association between 2009 and 2013. Currently, he is the chairman of the UK Biobased and Biodegradable Industries Association. His experience, as a consequence of his position in the industry in the beginnings and currently as chairman of the organisations involved in the making of the field, has made a valuable contribution to my research.

---

[30] Accessed from http://www.innoviafilms.com/innovation-centre/Innovation-Timeline.aspx on 9th Feb 2015.

[31] Information provided by Andy Sweetman in my interview conducted on 26th June 2014.

Clarifoil

Clarifoil, is also one of the oldest materials producers, which was registered in 1916. As a result of acquisitions Clarifoil became part of the Cellulose Derivative business of Celanese in 1923.[32] Celanese, currently an American multinational company, produces cigarette filter tows[33] from cellulose acetate. Clarifoil, the UK business of Celanese, is claimed to be 'a world leading product line of cellulose diacetate films.'[34] Clarifoil films have been the same ever since the company's beginning, and already complied with biobased, biodegradable and compostable standards.[35] The yearly production is about 10,000 tonnes. Similar to Innovia, Clarifoil material also comes in film format and has a defined application area, since it has been used in the packaging industry especially for luxury items due to its gloss. Like Innovia, Clarifoil has well-established industry relations. However, as distinct from all the other companies, although they touch on the 'green' features of their material their innovation is mainly focused on the permeability quality of the films, where they are qualified as anti-fog films for sports googles or the automotive industry, as described on their website.

---

[32] According to the information on the website of Celanese, 'Celanese is a global technology and specialty materials company that engineers and manufactures a wide variety of products' with a net sales of $6.5 billion in 2013; 'paints and coatings, textiles, automotive applications, consumer and medical applications, performance industrial applications, filter media, paper and packaging, chemical additives, construction, consumer and industrial adhesives, and food and beverage applications.' http://www.clarifoil.com/content.asp?ContentId=1&Page=About+Us&lan= on 10th Feb 2015.

[33] Filter tows are the fibre-like materials, of which cigarette filters are made.

[34] Information accessed from http://www.clarifoil.com/content.asp?ContentId=1&Page=About+Us&lan= on 10th Feb 2015.

[35] Derived from my interview with Sasha Herriot, the Marketing Manager at Clarifoil, on 12th May 2014.

Biome and Paul Mines, member of the Management Board of Lignocellulosic Biorefinery Network

Biome Bioplastics is a new materials producer in the field, based in the UK, with an annual production of 5,000 tonnes. On their website Biome is defined as 'one of the UK's leading developers of intelligent, natural plastics.'[36] Biome produces a range of bioplastic granules from potato starch or cellulose, each with different properties that are named as Biome Bioplastics. Biome defines itself as a company challenging itself with technically difficult applications.[37] My contact was the CEO of the company, Paul Mines, who has extensive experience in the chemical industry, having worked with Courtauld and Imperial Chemical Industries (ICI). He is also personally active in the bioplastics field, working to find financial and legislative support for bioplastics through his membership in various organisations. In 2014 he was selected to the management board of the Lignocellulosic Biorefinery Network.[38] His experience in the field and generous explanations have provided valuable information for my research.

[36] Accessed from http://www.biomebioplastics.com/company/ on 12th Feb 2015.

[37] Information derived from my interview with Paul Mines, the CEO of Biome, on 2nd May 2014.

[38] Lignocellulosic Biorefinery Network (LBN), is a government-funded body which aims to foster cross-disciplinary communities in the industrial biotechnology sector. The LBN is one of 13 collaborative networks set up by the Biotechnology and Biological Sciences Research Council (BBSRC) to boost interaction between academia and industry, and promote the translation of that research into benefits for the UK. Accessed from http://www.prw.com/subscriber/headlines2.html?id=5116 on 15th June 2015.

Reflection on the Sample of Materials Producers

The materials producers that I chose are the makers of the field with an interest in constructing bioplasticness. As the brief explanations of companies indicates, the materials that they produce and their paths and relations in the field are varied. I chose a sample that reflects this variety, as I believe that it provides better insight into the field, in terms of the variety of organisations, relations, scale, and hence interests. The sample that I achieved in the end exceeded my expectations, as I was able to arrange interviews with the top people of the significant players of the field.

It is also important to point it out about this sample that the 'substitution' routes of these companies are inevitably very varied, in that their materials are different, the production routes are different and the relations within the industry are different. Some have established relations from the 1960s like Clarifoil and Innovia, some are very young companies from the 2000s, without a defined sector in which the new material can find place. Therefore, I believe that this sample of materials producers presents a good range with which to inform my analysis in Chapter 5 regarding the production and substitution of materials.

3.2.3 The Products made of Bioplastics and their Makers

My third empirical focus is the bioplastic products. I considered that the three types of products that I identified – the bioplastic product itself, the packaging made from bioplastics, and the specialist products – would provide a variety in terms of articulating bioplasticness, as they have different use values and markets. I chose a group of products mostly based on access, and spoke to representatives of these brands, as I thought brands are 'makers of products' and are those who translate bioplasticness into the positioning of different products, by making bioplastics varyingly visible in products and in return configuring a bioplastics identity. I took care to sample a variety of products in which different qualities of bioplastics are made visible in different ways, i.e., some make the product itself look different, some use official labels of certificates in compliance with certain standards, and some make use of unofficial markers.

The Product Itself: Zuperzozial Tableware Range and Effektchange's Surfing Goods

Zuperzozial is a tableware range that consists of cups, plates, bowls and cutlery. Zuperzozial was founded in 2010, in the Netherlands as a sub-brand of Capventure, which is a company that produces kitchenware and tableware gift items. Hence, Zuperzozial's 'Raw Earth' range is composed of tableware items such as plates, cups, bowls, cutlery, jugs, trays and containers (Figure 3.1). Zuperzozial aims at creating a marketing angle by invoking the sustainability aspects of materials. The Zuperzozial Raw Earth collection is made of bamboo particles and bioplastic resin. The material in the Zuperzozial Raw Earth tableware range is made visible in a very distinct way. The coloured chipboard-like look of the material makes it very different in appearance from other tableware materials. They have an additional line, the Zuperzozial Just Sugar collection, where these items are made of PLA and carry a visible stamp that says in a speech balloon 'yes! I'm made of sugar!'

Figure 3.1 Zuperzozial Raw Earth range[39]

I spoke to Remco van der Leij, co-founder and chief designer of the company. As he states, the sales of Zuperzozial Raw Earth are about 400,000 items per year. Van der Leij explains, this number is only about 1/10 of a traditional batch of injection moulding,[40] therefore,

[39] Image provided by Remco van der Leij, co-founder and chief designer of Zuperzozial.

[40] Injection moulding is a plastic production method, where molten plastic is injected into pre-prepared moulds.

Zuperzozial has to use existing moulds at the converter, meaning that the form of the Zuperzozial tableware items will be similar to existing plastic products.

The other range of bioplastic products I identified are from Effektchange, which is a US based company that has a wide range of consumer products, from sun glasses to clothing. My main reason to contact Effektchange was their founder, Rob Falken, who in public profiles appears as an inventor. Falken had been developing products as a consultant, until recently when he founded his own company Effektchange. The first products of the company were various surfing goods, such as surf boards and wetsuits, as a consequence of Falken's passion for surfing and his personal search for more sustainable ways of doing this nature sport. Falken, as he explained in my interview, just wants to do everything in a more sustainable way, and he uses bioplastics to produce various consumer goods from surfing goods, to sunglasses, to crayons.

Figure 3.2 Rob Falken with some of his 'inventions.' A - The Sugar Cane Surfboard, B - Kryptex Pants Pockets, C - Reclaimed Wood Skateboards, D - Biobased Sunglasses, E - Nytrolite Paddle Vest, F - Biobased Fins, G - Spot Rescue Dye Pack, H - Hydrozote Tow Vest, I -Fiber-Reinforced Leash[41]

[41] Image accessed from http://www.surfermag.com/features/rob-falken-effekt-inventor/#Rzq0Go5yCLF8UPkC.97 on 22nd Sept 2015.

Packaging: The Packaging Bottle of Ecover and Tom Domen, the Long Term Innovation Manager

Ecover is a company that produces household cleaning items and packs its products in biobased bottles. Ecover's main products are cleaning products, where bioplastic makes up just the packaging. The company was set up in 1979 to 'create a phosphate free washing powder.'[42] Today they are a multinational producer of biobased and biodegradable household cleaning products. The company identity is formed around environmental values.

Ecover trademarked the material they are using, which is a mix of biobased plastic (a type of drop-in, BioPE) and recycled plastic, as Plantplastic. They are one of the first to use this material and also the packaging product, and they are consuming about 1,000 tonnes of Plantplastic a year in their bottles.[43]

Ecover makes their packaging bottle material visible in different ways. They have their own unofficial marker notifying the consumer of the biobased qualities of the bottles. They have run a large campaign called 'The Message in Our Bottle' (Figure 3.3) trying to make issues with bioplastics (plastic waste in the ocean) visible and make certain aspects of their kind of bioplastics (biobased and mixed with recycled ocean-retrieved plastics) upfront to match this issue.

---

[42] Accessed from http://uk.ecover.com/en/about-us/our-rich-experience/ on 25th Feb 2015.

[43] Information derived from my interview with Tom Domen, the Long Term Innovation Manager at Ecover.

Figure 3.3 Ecover's Message in their Bottles[44]

[44] Image accessed from http://your.ecover.com/campaigns/message-in-our-bottle/ on 7thOct 2015.

I wanted to talk to Tom Domen, who functions as Ecover's long term innovation manager as well as a public figure who advertises their bioplastic bottles in various ways. Ecover also presents him as the creative mind behind the bottles. Their customer service kindly provided his contact details, and after chasing him for over a year, I managed to have a Skype interview.

Specialist Applications: 3D Filament for Rapid Prototyping and the Tree Planting System of Natural Plastics

During a seminar I joined in the first year of my research, by chance I learnt that bioplastics – more specifically PLA – was used in rapid prototyping processes. I wanted to learn more about the material and its uses in this specialist application, which presented a different case than the market place of ordinary consumers and I thought it would be a good opportunity to observe the different 'calculations', using Callon et al.'s (2002) term, of materials. Besides, the material was not visible as bioplastic or any other quality. Rather, it was referred to as PLA, its scientific name.

The Rapid Prototyping Laboratory is a designated space in the building of Engineering at Lancaster University. However, some scientists also have machines in their offices, so the rapid prototyping lab stands for the practice rather than the place. Rapid prototyping, as the name suggests, is a way to produce prototypes or parts for industrial applications, or for test purposes. Briefly, this process does not require a mould to be produced, and the rapid prototyping machine takes the 3D coordinate information about a model from the computer model and applies it to reality. In simple terms, the machine uses thin threads of plastic material, melts these in the nozzle at the tip of the operating arm and lays it on the bed, where the model is built layer by layer with the molten plastic solidifying. However, as is usually the case for rapid prototyping processes, the production in the lab is quite minimal, as little as a few kilos of PLA per year. I spoke to three scientist engaged with rapid prototyping to learn more about how they use bioplastics and what they make out of it. They made test models, for example to observe the behaviour of water in propellers, bone scaffolds, and used PLA to prepare model beds or moulds, as it dissolves easily. The significance of bioplastics in these applications was simply the fact that it disappears and dissolves.

The other specialist application I looked into was the tree planting Keeper® system of Natural Plastics. As my contact person who is also the owner of the company stated, Natural Plastics has planted 30,000 trees over the world. This tree planting system is composed of various specialised bioplastic products that helps to keep the tree stable when first planted, where the parts biodegrade under soil in some time. In this case as well bioplastics were important simply because they disappear.

Reflections on the Sample of Products

I presented my product sample according to my initial considerations. However, as my findings showed for the materials producers and the brands these categories do not exist in the sense that making a product/material is specialised and requires specific and detailed knowledge of the makers, regardless of it being a packaging that might appear simple to the ordinary consumer, or a specialist bone scaffolding for medical purposes. And clearly these products needed to be marketed differently for different markets. While this sample is rather opportunistic, it reflects the fragmented field made up of enthusiasts, opportunists, new brands, as well as organisations devoted to and identified with environmental wellbeing.

Moreover, the product side of the research was not limited to these interviews only. In my interviews with the materials producers I obtained extensive information about the product side of the story as well. This, as I found out, was a natural consequence of the close-coupled relationship and orientation of materials to products, and of making a new field. Also, *Bioplastics Magazine* became an important source of additional information, with reports and interviews from the product side and its marketing. This rather fragmented range of products is consistent with the development of the field and random nature of what actually gets made from bioplastics.

3.3 The Interview Processes

After identifying the actors above as key makers of bioplastics, I went on to arrange interviews, using different techniques to get access. With those who have shared contact information publicly, namely, Effektchange, Natural Plastics, Zuperzozial, and, *Bioplastics Magazine,* I had contact through phone or emails. With Effektchange and Natural Plastics, I persisted over months and was finally able to arrange interviews.

With some of the large companies, Ecover and Clarifoil, I obtained contact details through customer enquiry. In the case of Ecover, I had requested to talk to Tom Domen specifically, due to his public profile as the innovator behind Plantplastic bottles of Ecover. The customer service of these companies took my research seriously and directed me to relevant people. However, I should note that the approaches that failed in this way are numerous. Reaching the actors who I wanted to interview was often very difficult for various reasons.

One of the milestones of my research was trying out social media tools. In one of my desperate last attempts, to my surprise Andy Sweetman, the former chairman of European Bioplastics Association, accepted my contact request. He later on explained that social media platforms were a recent technique they were trying out to reach small scale users of bioplastics. In one of my interviews he mentioned that in addition to regularly exhibiting in the trade fairs in particular sectors, such as tea and coffee, where there are a lot of natural and fair trade market positioning, recently, Innovia has started to use social media platforms:

> *We are starting to use tools such as XXX, more proactively than ever before, which is interesting. From a marketing perspective it is a very interesting tool actually. People haven't really understood the potential power of XXX. So, we are trying, by the way I am not saying we are good at it, because it is quite a different approach, but we are unusual in that we are even trying it. Most companies haven't really realized the potential power. So for example, one of my teams, is looking at health bars, granola bars, whatever you wanna call them, nutritional bars, she has identified the number of companies who she thinks might be motivated, by looking on the internet, and then she is using XXX to get the contacts of the people to talk to, which is potentially very very powerful, very interesting, so we are trying to use more modern techniques.*

So my use of social media tools intersected with the company's interest into the same media to find new markets. As a result, I was connected with Sweetman and he kindly agreed to invite me for a visit to their Research and Development unit in Wigton, UK. Furthermore, my contact with him through this social media platform opened up a whole new dimension for my research. The platform works as follows: When I am connected to person X, those people who are also connected to the person X that I want to connect to, receive the information that I am also connected to person X. So, in this case my connection with Andy Sweetman has worked in a way that facilitated trust in my researcher profile and I could connect to Paul Mines from the Management Board of Lignocellulosic Biorefinery Network and CEO of Biome Bioplastics, to Catia Bastelli, the CEO of Novamont and to Marc Verbruggen – CEO of NatureWorks.

Due to the diverse landscape of bioplastics field, these respondents were located in different parts of the world. My respondents were also very busy people. Thus, arranging the visits and interviews and conducting them took over a year. My final sample was close to my original target and actually even unexpectedly richer on the materials producers' side. I visited the companies when possible, and otherwise conducted phone or Skype Interviews. Some interviews were strictly one hour, while others lasted 1.5 - 2 hrs, after which I got tired as a result of the vast amount of information I had obtained as well as trying to reflect on it. In those cases I took the initiative to end the interview, and asked for another appointment.

I visited Innovia's R&D centre in the UK and interviewed Andy Sweetman three times and visited Zuperzozial's design office and showroom in the Netherlands and interviewed Remco van der Leij, twice, and also interviewed him once on the phone. The visits to the R&D unit of Innovia and Design office and show room of Zuperzozial were enjoyable and rich in visual and tangible data. I would sit with my interviewees around a table, play with the products and talk about them without any time constraint. Being a designer, of course, my attention would occasionally shift to other issues related to production and details of products. These information later on proved to be useful details for my study. Nevertheless, I also managed to go through the questions that I had planned to ask and collected valuable data for my research.

The other interviews were conducted either on the phone or on Skype-video call. I found the phone interviews the most convenient, compared to video calls or visits, as I could just focus on my notes and did not have to demonstrate that I was still listening as well. In my office or flat I could just concentrate on my interviews, listen to them carefully, take notes while the interviewees talked and at the same time produce additional questions to elaborate on topics that were interesting for my research.

3.4 Collecting Data - Analysis Feedback Loop

I did not prepare a single semi-structured interview for all of the actors, as such an approach would not have provided me adequate data given the variety of actors who I spoke to as well as the multiplicity of materials, products and networks. I followed what I will call a progressive data collection process, where I added onto the issues of previous interviews with each new interview I conducted.

Before each interview I engaged in thorough research about the company and the person I was going to talk to, reading the news reports about the company to note any issues at stake. As each company provided different levels of information on their websites, the questions had to be framed in a way that took the specifics about their products and missions/objectives into consideration and that enabled me to go into details of specific material-product relations. So, for each interview I prepared a new set of questions and prepared myself on ways to elaborate possible issues. Before conducting the interviews I discussed with my supervisors my interview structure and how to develop questions. After a while I gained competence and could proceed on my own.

For me there were some personal issues at stake. I come from a background where things and materials are taken as they are, or at best as designed by some designer. Although my whole approach was about saying that there are other ways of looking at things and other ways through which things come to be, still in the beginning the disciplinary indifference to certain issues kept me from asking the right kinds of question or recognising a point for further enquiry. My background assumed that materials have fixed meanings and properties, and tools to choose them appropriately are the primary concern, not how those properties came to be of significance, or more correctly are enacted in certain arrangements. Internalising this approach and enacting it in an interview setting and being able to think and ask questions as a sociologist would was quite a transformation for me. Also the language of the respondents I spoke to was technical and definite. To see beyond the taken for granted ideas and language of industry people to see the obscured relations and techno-social processes was a challenge. At the same time, I believe that my specific interest and training in product design lead me to open up areas that might be invisible to people from other backgrounds, and to attend to information relevant for my specific focus on material-product relationships. It also made it easier for me to understand the industry people who I spoke to.

All interviews were recorded with the interviewee's consent. I transcribed the interviews and made notes on them. In most cases I conducted at least two interviews with each respondent, this way I found it easier to listen to my recording a couple of times, read my transcription many more times and spot the interesting issues on which to ask further questions. So I would prepare my second interview based on the new discussion areas opened up in my previous interviews. Interviewing the same person the second time also enabled me to ask for further explanation on the points that I missed on the first interview.

I also identified reappearing issues across different respondents as issues that would be interesting to follow up. So my data collection and analysis processes fed back into each other. I continuously analysed my data and this informed my upcoming interviews. As the main points of my thesis got clearer, such as categorising, substitution and visibility, I guided my interviews more in that direction. I was careful to avoid referring to the information that I had obtained from other companies or to provide a specific source for my information. Occasionally, however, my respondents referred to other companies, or asked me who else I had spoken to.

The respondents I interviewed that are grouped under the key makers of the field (so after the first set of interviews with the representatives of local shops and retailers) had, in particular, a totally different attitude and knowledge level than those in the first set of interviews. Mostly they were very interested in any kind of research, and were in control of their field and company. They were talkative and encouraging.

The language and content of the data I collected from respondents varied. To support my analysis better I preferred to quote the actual words of my respondents. However, naturally in spoken language there are odd sentence constructions and unorganised narratives. Thus while quoting I had to cut some parts out of the transcript, but I took care not to change the meaning in that context.

3.5 Concluding Remarks: Limits of My Approach

In this chapter I outlined my first exploratory attempts to come to terms with the field and thereby explained its multiplicity. I started with the products themselves, as I found them and looked for their relationships to materials of which they are made. I then described the main empirical resources that inform the rest of the study, and how I collected and analysed the data.

This discussion was inevitably structured around the categories that I developed to make sense of this new field, where these categories were shaped according to my concerns in attending to materials and products separately yet as interconnected. Surely there could be other ways of seeing the relationships and actors of this field.

Another challenge even within my own framework is that the field is exponentially growing. This means that the relations, materiality and practices that make up the field are changing. New companies or specialisation areas take the field in new directions. So my research was limited to what I learnt from a handful of spokespersons and as wide as possible search on secondary searches and related groups at a particular moment in time. What the field will become is not known yet. As my research showed, what started as a field focused on biodegradability is now lead by an orientation to biobased qualities. In time, new terms are produced, and these involve bioplastics in different networks and valuations. Currently, there is not even a dominant sector. This means that I am not able to sort out a focus based on what bioplastics became and so what was, in retrospect, most relevant to this becoming. Schatzberg (2003), for example, was able to focus on certain sectors in which the symbolic values of aluminium were the most influential. Nor am I able to rely on cultural historical information, as Shove et al. (2007) do for the case of plastics used specifically in household practices. Rather I have an emerging industry that is rapidly in the making.

Also in my research I did not focus on those who oppose to the use/production of and values offered by bioplastics. I recognise their influence and give voice to them as reflected in my interviews. However, clearly they are influential in the valuation and the direction that the development takes. Nor was my study based on extensive inside knowledge on how the companies really work and their formulas for composing materials. I rather relied on the information that I got through the sources described above.

Although I do not claim to have drawn the whole picture of the field, I did attempt to speak to CEOs and managers of, and experts in, the companies that I thought are the most appropriate sources for the making of the field. I was limited to what they made available and visible for me, however as I conceptualised 'making visible,' this showed me their interest in a particular positioning as well as what counts as the field for them. Of course, I assume these spokespersons of the industry have an interest in promoting the field and their companies. Nonetheless these spokespersons act according to how they see the field, and I consider this to be how this field is in fact made in important respects.

CHAPTER 4

DEFINING NEW MATERIALS:

CATEGORIZING AND STANDARDISING

> *Standardization is very important for innovation, because some innovations are visible to the customers, so are self-evident, some others not. […] Without the standard, without a certification system, anybody can make any claim.*

Francesco Degli Innocenti, Director of the group for Ecology of Products and Environmental Communication, Novamont
Quotation from my interview on 12th May 2015.

In the previous chapters I elaborated on my conceptualisation of materials as made in their relations, and materials and products as co-constituted. I explained that such a conceptualisation required me to develop methodological strategies that will enable me to capture the dynamic field of bioplastics. I made the decision to follow the processes of substituting other materials with bioplastics and making certain qualities of bioplastics visible. I then proceeded to explain my empirical resources. These chapters introduced the central concepts and observations on which the empirical analysis of my study is based. The current chapter is the first chapter that analyses my empirical material more closely. It explores categories of, and formal standards pertaining to, the definition of bioplastics.

Unquestionably, the categories and formal standards *make* bioplastics in that they define the criteria and scientific specifications for the materials to be named or be certified as bioplastics, and thereby define their boundaries, as well as positioning bioplastics in relation to other materials.

However, I adopt a more nuanced perspective on categories and standards by taking ideas from Bowker and Star's (2000) comprehensive study of the ways in which categories, classification systems and standards organise and inform daily lives, and Busch's (2011:2) extensive account of the ways in which standards shape the physical world, 'social lives and even our very selves.' Busch (2011:13) states that:

> [Standards] are means of *partially* ordering people and things so as to produce outcomes desired by someone. As such, they are part of the technical, political, social, economic, and ethical infrastructure that constitutes human societies. [Emphasis in italic in the original text]

Busch suggests that categories and standards are made by certain actors and hence they are charged, in that they are created, developed and mobilised within certain social and technical arrangements, by certain groups for certain aims, according to their respective power relations. Moreover, in return, by means of creating boundaries, positions and values, categories and standards 'constitute human societies', as expressed in the quote; categories and standards affect the practices and the socio-technical situations in which they emerged, those who are involved in their creation and those to whom they apply.

Bowker and Star elaborate further on the role of categories and standards (2000:5-6):

> …each standard and each category valorizes some point of view and silences another […] For any individual, group or situation, classification and standards give advantage or they give suffering. Jobs are made and lost; some regions benefit at the expense of others.

This quote shows that categories and standards matter because of their power to exclude – as well as to include – certain things, groups, practices, and points of view. So these boundaries create advantageous situations for certain groups, certain points of view at a certain period of time. I conceptualise bioplastics' categories and standards as *created* by different actors and informed by their respective interests in bioplastics, in and through varied social and technical arrangements, values and power dynamics.

As such, looking at the development and change in categories and standards pertaining to bioplastics does not only show me the definition and boundaries of these new materials, but also reveals the types of actors involved in their making, the actors' respective interests, the various technical, social, political dynamics involved, and what counts for whom.

A focus on categories and standards, is, on the one hand, a conceptual framing which helps me to open up the observation I pointed out in the introduction of the thesis about the varied and dynamic definitions of bioplastics, and so to explore the making of materials. On the other hand, it is a methodological tool that unfolds the different actors involved with and valuations of bioplastics. This helps me both to understand the field better and to portray the complexity of the field in terms of the related actors and stakes around bioplastics, and the sociotechnical arrangements through which bioplastics are enacted.

Bowker and Star (2000) and Busch (2011) are primarily interested in the invisibility of categories and standards, the fact that they are silently embedded in the infrastructures of daily lives, and in unfolding the relations making them up in order to make the invisible visible. However, I realise that in this newly emerging field, categories and standards pertaining to bioplastics are a means with which to make the qualities of new materials visible. By contrast, then, I focus on the categories, formal standards, certification labels and values that are made visible in the field, and explore who makes different categories and standards, for whom is their visibility useful, who uses them and who changes them. My aim is to be able to identify social, commercial, political and technical relations that are shaping bioplastic materials and, in different ways, shaping the products into which these materials are made.

The account in this chapter is mainly informed by my analysis of the largest international trade magazine in the field, *Bioplastics Magazine*,[45] and my interview and email correspondence with Michael Thielen, the editor of the magazine. As explained in Chapter 3, trade magazines are at a critical time in the development of the industry, important sources of information as they define and shape the field, reflect the developments on the field, and connect different stakeholders. I have undertaken a systematic reading of all 42 issues of *Bioplastics Magazine*, from 2006 to 2013. I focused especially on the sections titled: 'Editorial,' 'Basics' – where definitions of bioplastics are made and contributions from different actors are included, and 'Opinion', where points of view of the trade magazine on related discussions is conveyed. I also analysed the published discussions about the definition of bioplastics and related

---

[45] Michael Thielen, the editor of the magazine, provided me with temporary access to the online archive of the magazine. Hence, when I refer to the magazine there are no page numbers, rather I provide the title and name of the contributor of the related reports.

categories as represented in *Bioplastics Magazine*, as well as the websites of related organisations, groups, standards and certification organisations, and government procurement agencies – who are all variously engaged in defining bioplastics.

In working through the categories and formal standards of bio plastics, I develop my own categories around which to structure the chapter. This is because the categories and standards pertaining to bioplastics are practically impossible to separate out from each other, and yet there is still value in examining them separately for the purposes of this chapter. The first analytic category I discuss (Section 4.1) is an 'umbrella category' in which the varied field and its different components are represented under one heading, 'bioplastics', as if this constituted a single identifiable material and related industry. I show that the 'umbrella category' is established and evolves in and through *negotiations* with various actors and their respective interests in the field and stakes around bioplastics. This section significantly reveals that bioplastics is composed of multiple industries.

In the next section (4.2), I consider the emergence of the two core 'sub-categories': 'biobased' and 'biodegradable' plastics, as reflected in *Bioplastics Magazine*, and other secondary sources. I examine the controversies around the definitions of these sub-categories, their shifting importance and how these sub-categories are taken up differently – both as positive and negative values – by different actors and across what are becoming separate industries. I also elaborate on the ways in which the development of bioplastics is *channelled* in certain directions in and through the different valuations of relevant sub-categories.

Next (Section 4.3) I tackle 'formal standards', my third organisational category, especially the standards that are named in the definitions offered by the sources listed above, and those that are used by certification bodies. As Bowker and Star (2000) observe, categories that are standardized are the ones that pass the borders of individuals or local communities or temporal practices. Thus, formalised standards are more widespread than descriptive categories. I show that the standards and certifications of bioplastics make certain qualities visible (Cochoy, 2005), and exclude some other qualities. But in the specific case of the 'starred' biobased certification systems, certificates of biobased *encourage* the development of biobased production according to the regional development plan of the US government.

This chapter ends with a twist in the narrative (Section 4.4), where I flag up the fact that in the market place the 'products', rather than the materials, are certified, and I consider the implications of this in terms of the relationship between materials and products.

My analysis in this chapter shows that categorising and standardising are means with which the actors *negotiate* the value of and relationships pertaining to bioplastics. Through these negotiations the relationships between these actors, who are variously involved with making bioplastics, are established, settled and maintained, which in effect makes bioplastics. These means also *channel* and *encourage* the development of bioplastics in a certain direction, as well as being influenced by the materiality and values they reproduce. This provides me with a radical insight into the making of materials. It reveals that even the categories and definitions of materials themselves are socially and technically made, by being *negotiated* through and *channelled* and *encouraged* by the relevant actors.

4.1 The 'Umbrella Category' Bioplastics: Its creation and usages

In this section I try to pinpoint a beginning for the category bioplastics, as well as to explore the actors and interests in the field through the multiple definitions and valuations of bioplastics. My analysis in this part reveals that what is presented as a single industry, under the 'umbrella category' bioplastics, is, actually, comprised of multiple industries.

Interestingly, the materials that are currently named as bioplastics have existed for some time; the materials and the technology to produce bioplastics at large scales have been present for over a century as well as some new versions that were invented after the 1990s. However, these materials were not named as bioplastics. As the history of plastics showed, the first plastics Casein, Shellac and Celluloid, which were invented in the late 19^{th} century (Stevens, 2002; Katz, 1978; Fiell and Fiell, 2010), were what today would be called bioplastics, in that they were biobased plastics. One such example is Celluloid. Although it found large scale production and applications, its bioplastic-ness or biobased features were not upfront, nor was it named as such, until recently. It is as though bioplastics did not exist as a separate plastic category for material producers, processers, brands or consumers, until they started to be categorised as such. I take this as a starting premise, the fact that ordinary consumers, as well as scientists, actively construct what they perceive as a fixed material category, and I seek to show how it works for bioplastics.

Eugene Stevens, a chemist, uses the term 'bio-plastics' as early as 2002 in his book *Green Plastics: An Introduction to the New Science of Biodegradable Plastics*. 'Biodegradable plastics,' 'green plastics' and 'bio-plastics' are used interchangeably in this engineering oriented book. Another possible starting point is a news article from 2003, in 'Plastic News,' an online platform encompassing the whole of the plastics industry. The term 'bioplastics' appears in this report of a possible investment of Toyota on bioplastics, namely PLA.[46]

During the course of 2005, there begins to be more systematic usage of the term. For example, the industrial working group IBAW (Interessengemeinschaft Biologisch Abbaubare Werkstoffe – Industrial working group to define compostability and biodegradability of plastics), which was founded in 1993, changed its name to 'European Bioplastics Association' at the end of 2005.[47] This shows a clear interest in naming certain type of materials as 'bioplastics.' That same year, the European Bioplastics Association organized a conference in Brussels, Belgium entitled the 'Bioplastics Conference,' which has been continuing annually to date under the same title. The first of these conferences brought enthusiasts, engineers, and scientists together. This conference also formed the foundations of the trade magazine *Bioplastics Magazine*, as the editor of the magazine Michael Thielen stated in an interview.[48] *Bioplastics Magazine*, which carries the name bioplastics in its title, published its first issue in 2006. Again, in 2006, the 'Material Data Center,'[49] which is an internet portal and extensive database for plastics, started to feature biopolymer (a more scientific name for bioplastics)

---

[46] Accessed from http://www.plasticsnews.com/article/20030616/NEWS/306169973/supplier-news on 27th Dec 2013.

[47] Accessed from http://en.european-bioplastics.org accessed on 29th Dec 2013.

[48] Information from my Skype interview with Michael Thielen on 10th Oct 2013.

[49] 'Material Data Center' was originally launched for traditional plastics and is used by hundreds of professional specialists 'to get information about available materials and their characteristics.' Information accessed from www.materialdatacenter.com on 9th Feb 2013.

information in their extensive database.[50] Based on these developments, which show the efforts to produce a definition and to gather different interests under one 'umbrella category' of 'bioplastics', I point to 2005-2006 as an approximate start of the use of the term.

I take the definitional work of *Bioplastics Magazine* and the discussions reflected on the magazine as the starting point for my research. I orient myself towards *Bioplastics Magazine* both for practical reasons, since the field is so diverse, and also as result of the position of the magazine, as the most widely accepted reference in the field and as the only international trade magazine devoted to bioplastics.

The first issue of *Bioplastics Magazine* defines bioplastics as follows:

> *The basic idea behind bioplastics is taken from nature's cycle. […] This cycle is the role model for bioplastics. […] Bioplastics are man-made plastics (polymers) which can be processed by established plastics processing technologies such as injection moulding, blown or cast film extrusion, blow moulding, extrusion etc. and which are A) based on (annually) renewable raw materials (RRM) or B) biodegradable.*[51]

This is the definition of the 'umbrella category' bioplastics, which was widely accepted at that time. However, the definition and the boundaries of category bioplastics – what can be included in the category of bioplastics and what cannot – is an ongoing process as reflected

---

[50] *Bioplastics Magazine*, 01/2006, section 'News', 'Plastics database now includes bioplastics', by Michael Thielen.

[51] *Bioplastics Magazine,* 01/2006, section 'Basics', 'Definition of "Bioplastics"', by Michael Thielen.

in the discussions in the magazine. In several issues, by asking the consensus of the audience of the magazine, these boundaries are tested and negotiated as a result of newly emerging interests in bioplastics from different groups of actors. For example, in the 10th issue of *Bioplastics Magazine*, the 'Editorial' announces a broadening of the category bioplastics:

> *We [as* Bioplastics Magazine*] hesitate about including bio-fibres within the scope of our magazine. However, the initial successes in attempting to combine such natural fibres with bioplastics* <u>*as the matrix resin*</u> *convinced us that they belong in Bioplastics Magazine. [Underlined my emphasis]*[52]

This broadening of the category bioplastics as such points to the influence and effort of resin producers to be included in the category. To elaborate further on these changes in the definition of bioplastics, the 'Editorial' section of the 15th issue of the magazine discusses whether to include composites in the category bioplastics, and addresses these types of materials as 'compound materials' or 'material combinations.'[53] This presents one of the ongoing discussions in the magazine, where in the 41st issue of the magazine the 'Editorial' section poses the question: 'How should natural fibre reinforced or filled conventional plastics be considered?' [Quote not edited][54] As I see through my reading of the magazine the scope

---

[52] *Bioplastics Magazine* 02/2008, section 'Editorial', by Michael Thielen.

[53] *Bioplastics Magazine* 03/2009, section 'Editorial', by Michael Thielen.

[54] *Bioplastics Magazine* 05/2013, section 'Editorial', by Michael Thielen.

of the bioplastics field is discussed by the magazine acting as the mediator of these different interests, reconciling existing influential groups with newly emerging areas.

The type of materials to be named as bioplastics is of course one of the core issues with which the magazine and the industry are concerned. As revealed in several issues, *Bioplastics Magazine* works to distinguish bioplastics from a type of material which the magazine categorizes as 'oxo-degradables' or 'oxo-biodegradables.'[55] *Bioplastics Magazine* is concerned that these oxo-degradable materials are represented as bioplastics and reports with a judgemental tone that 'their protagonists may like to see them included' in the category bioplastics.[56] However, according to the magazine, oxo-degradables are 'a completely different group of materials;' These 'materials, based on polyethylene (PE, from fossil resources), but containing additives to promote degradation of the material, are a contentious issue, as they pose several concerns regarding safety and eco-toxicity.'[57] The concerns regard the fact that oxo-degradables fragment into smaller pieces not visible to the eye, but that still remain intact without biodegrading. Therefore, they persist in the environment and cause 'bioaccumulation of liberated regulated metals and PE fragments in organisms.'[58] Here

[55] *Bioplastics Magazine* 01/2006, section 'Basics', 'Definition of "Bioplastics"', by Michael Thielen. *Bioplastics Magazine* 01/2009, section 'Editorial', by Michael Thielen; section 'News', 'Two new laws in Canada', 'Use of Oxo-Additives implicates loss of Warranty' and 'Bag Manufacturer to Stop Advertising Environmental Claims for Oxo-Products' by Michael Thielen; section 'Politics', 'Biodegradability... Sorting through Facts and Claims' by Article contributed by Ramani Narayan University Distinguished Professor Department of Chemical Engineering & Materials Science Michigan State University, USA.

[56] *Bioplastics Magazine* 01/2006, section 'Basics', 'Definition of "Bioplastics"', by Michael Thielen.

[57] *Bioplastics Magazine* 01/2006, section 'Basics', 'Definition of "Bioplastics"', by Michael Thielen.

[58] *Bioplastics Magazine* 01/2006, section 'Basics', 'Definition of "Bioplastics"', by Michael Thielen.

the magazine refers to the European standard EN 13432 for biodegradability to justify their point about exclusion of oxo-degradables, as these do not comply with the standard and so should not be included in the category bioplastics. However, they still discuss the topic of whether to take a position against oxo-degradable materials and invite responses from their readers. As reflected on the magazine, in reports from and correspondences with oxo-degradables producers, there are on the one side the producers and users of oxo-degradable materials, who have an interest in including oxo-degradables in the category of bioplastics. On the other side, there is the magazine and other producers who comply with the standards, and who want to keep the integrity of the bioplastics field and their market advantage within it.

To an extent, then, the magazine acts as an arbiter of what to include in the category bioplastics, what not to include, and what are the important terms and how to define them are *negotiated*, by the different actors. In a self-evaluation of their use of the category bioplastics, Thielen, the editor of *Bioplastics Magazine*, explains as follows:

> *We hope that the industry follows us [in their definition of bioplastics], we are* the *magazine of this industry. If a great portion of the industry would disagree, they would ask us to publish different things. So, as long as they do not disagree, as long as they read our magazine and buy advertising, we are in the impression that they agree to this kind of definition.*[59]

---

[59] Information derived from my interview with the editor of *Bioplastics Magazine*, conducted on 10th Oct 2013.

His quote reveals the commercial dynamics that are involved in definitional work and that make up the industry. Thielen explains further that the magazine is funded by the advertisers, who are mainly materials producers, by the businesses and entrepreneurs who visit the conferences and trade fairs that the magazine organises, and by the subscribers to the magazine. These actors, from within their various interests in bioplastics, in effect *negotiate* the content and terms of the field.

In defining the bioplastics field, *Bioplastics Magazine* works in close collaboration with the European Bioplastics Association, which is a trade association that represents interests of 70 member companies, including the agricultural feedstock, chemical and plastics industries, as well as the industrial users and recycling companies throughout the European Union.[60] The members of the association, who are engaged in the definition of bioplastics, point to a multiplicity of bioplastics in terms of industries, stakeholders and interest groups involved.

The objective of European Bioplastics Association, as explained on their website, reveals yet other stakeholders in the field and their respective interests. The association has the goal of 'building a fact-based and quality-driven image of bioplastics', which includes 'establishing product standards and labels', 'creating communication tools and a common language' and encouraging 'legislative frameworks to set up suitable market introduction conditions.'[61] As can be seen from these objectives, defining bioplastics involves the creation of value, as well as close relationships with the standards making organisations and the relevant governments.

---

[60] Information accessed from http://en.european-bioplastics.org on 29thDec 2013.

[61] Information accessed from http://en.european-bioplastics.org on 29thDec 2013.

And the stakeholders in bioplastics involve those who might be affected by the valuation, legislation and standardisation of bioplastics.

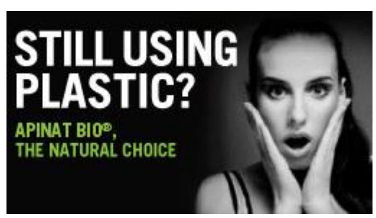
Inevitably, there are stakeholders who use the term bioplastics in different ways or make up their own term, such as green plastics, environmentally friendly plastics and the like, to create favourable positions in marketplaces. As the category bioplastics does not have a formal definition, its usage is flexible and unsteady, and can easily lead to conflicting definitions. The European Bioplastics Association and *Bioplastics Magazine* regard the different usages as 'misrepresentations', as reflected on the discourse of the magazine and the website of the association, and therefore try to work against these variations to define the field according to their definition and their interest groups. For my purposes, however, these 'misrepresentations' point to the multiplicity of the field; the different actors that are involved in the making of the field, such as industries, consumer groups, governments, social groups, and their conflicting and contradictory motives, such as environmentalist, or economic concerns. As the field develops and new positions and opportunities arise, new interests are formed, and the category bioplastics continuously changes.

However, looking at categories only through actors, their political, economic, and various interests and the social and technical arrangements in which they are situated, draws a partial picture of the dynamics related to categories. I draw on Bowker and Star (2000:64) again, where they state that the 'classification systems in general reflect the conflicting, contradictory motives of the sociotechnical situations that gave rise to them.' These 'motives' and 'sociotechnical situations' are shaped according to what is taken to be good or valuable at a given time. Why and how bioplastics came about as a category at this particular time in history, and with a *positive* valuation of certain features, is arguably partly related to the heightened discussions in public media about the damage humans are causing to the ecosystem and nature, and about the effects and causes of climate change. It was not possible to talk about recycling, energy recovery, carbon footprints, or material waste at the beginning of the 20th century when biobased plastics were forming a new industry. Indeed, interestingly, the first petroleum based plastics, such as Bakelite, were valued precisely because they were not using bio-sources and because they were not biodegradable. Meikle (1997a:68-74) in his cultural historical account of plastics explains that 'modern miracles' of plastic were valued as they do not come from nature, and petroleum was seem as an unlimited source at that time. Further value was added by nature's inability to break down plastics and by plastics' ability to overcome 'imperfections' of nature. 'Biodegradability' is simply something that decays, and 'biobased' simply means using plant sources and so renewable and reusable carbon (as opposed to petroleum based plastics), and these terms are rendered valuable within aspects of changing understandings of sustainability.

I draw on Kopytoff's (1986) ideas to elaborate on the link between categories and valuation. Kopytoff in his account of the economic value of commodities observes that the human mind categorises things to make sense of and adapt to the world. He states that the production of commodities, by which he means things with exchange value, requires them to be 'culturally marked as being a certain kind' (Kopytoff, 1986:64). He explains that culture enables value categories to be formed that are somewhat homogenous groupings of singular things. Kopytoff (1986:70) states that 'in the realm of exchange values, this means that the natural world of singular things must be arranged into several manageable value categories – that is, different things must be selected and made cognitively similar when put together within each category and dissimilar when put into different categories.' This observation is similar to the observation of Callon et al. (2002) I explained earlier, where they explain that qualities of goods are accomplished through processes of creating distinctions, as well as establishing the singularity of the good.

I observe that bioplastics are valued as a natural and environmentally friendly type of material, as such one that opposes the environmentally harmful and ‘artificial’ connotations of traditional oil-based plastics. Even the prefix *bio-* in the name, seems to define this type as biologic, going well with nature, being good for nature as opposed to artificial or synthetic and harmful for nature. Natural, being close to nature or coming from nature, is part of the definition of the category bioplastics, as represented by the companies advertising in *Bioplastics Magazine*. This is reflected explicitly in the company and product names such as: NatureWorks, NatureFlex, or various names that include prefixes bio-, eco-, or variations of the word ‘plant.’ Company mottos, such as ‘ApinatBio – The Natural Choice’, ‘NatureFlex – Packaging from nature, Packaging for nature’, ‘FKuR – Plastics made by nature’, ‘Myriant – Chemistry refined... Naturally’, ‘Biolice – Loves your environment’, which most of the time touch on the natural aspect are also revealing in this sense (see Figure 4.1).

FKuR
plastics - made by nature!®



Myriant Chemistry Refined...Naturally

Figure 4.1a Motto of FKuR[62] 4.1b Motto of Apinat Bio[63] 4.1c Motto of Myriant[64]

[62] Accessed from http://www.fkur.com/ on 7th Oct 2015.

[63] Accessed from http://www.apinatbio.com/eng/home.php on 7th Oct 2015.

[64] Accessed from http://www.myriant.com/products/bio-succinic-acid.cfm on 7th Oct 2015.

The category bioplastic and its value are tied to a broader set of concerns raised around nature and its materiality. Bioplastics resonates with a conception of nature as something that needs to be protected from humankind's own destructive force. As such, bioplastics and its natural value appeal to consumers' moral concerns regarding environmental issues and bioplastics take on the responsibility of taking care of the environment.

I have argued so far that valuation is central to the making of categories. Schatzberg (2003:226) in his business historical account of aluminium, argues that symbolic values of materials – aluminium in his case – 'influence technological innovation through their role in shaping expectations.' Schatzberg explores the ways in which aluminium's symbolic values – by being categorised as metal – shape its identity, as well as its development and future, where, as he argues, the aspirations and ideas about aluminium directed research and development activities and industrial investment in aluminium. Valuations are informed by the materials but also shape what materials become by shaping aspirations about it. The naturalness, or 'bio'-ness of bioplastics likewise shapes the identity of this new material, as well as its future by directing research and development and investment in bioplastics as the future of plastics.

The 'bio' positioning also involves bioplastics in value discussions on the larger biotechnology field, such as the negative valuation of the bio-fuel industry, as using up food sources for humans. *Bioplastics Magazine* responds to these discussions by trying to position biofuels and bioplastics as different approaches:

> *I believe (and I am not the only one, I assume) that biofuels are not exactly the smartest approach. I don't think it is too clever to burn agricultural products directly. It's much better to produce useful (for example*

> *bioplastics) products and use and recycle these as often as possible. After a long and useful life and, wherever possible, 'cascade' recycling, the material can still be incinerated to recover the energy stored in it. And by the way: the amount of agricultural crops used for bioplastics is much lower than that used for biofuels.*[65]

This quote shows an attempt to position bioplastics as a 'smart' way of using natural sources, by comparing them with biofuels. It also shows that the biobased aspect of bioplastics is made prominent, while biodegradability is obscured so as to position the field as favourable in this discussion. This on the one hand shows that the field is on the move, in terms of positioning and defining an identity. On the other hand, it shows that the usage and boundaries of bioplastics shifts depending on the context. For example in this context, bioplastics shifts towards being biobased and durable, rather than being compostable and disposable.

In sum, this section identified a start date for the usage of the term bioplastics. By means of focusing on the changes in definitions and boundaries of bioplastics, it demonstrated the variety of the actors, their respective interests, and the socio-technical arrangements that reveal the bioplastics field as comprised of multiple industries. I argued that bioplastics are made in *negotiations* among different stakeholders, their respective interests and broader valuations of the category. What is considered important and what is taken to be valuable at a given period of time informs categorisations of bioplastics. This is a point I will pick up in the

---

[65] *Bioplastics Magazine* 06/2008, 'Editorial' by Michael Thielen.

next section, exploring how the 'sub-categories' of bioplastics are taken up differently by different actors as the wider categories shift.

4.2 Sub-categories: Biobased and Biodegradable

So far I have dealt with the 'umbrella' category of bioplastics, which presents the field as if one single industry, while acknowledging that bioplastics are not one type of materials, nor is there a single bioplastics industry which is comprised of a single set of actors. Sometimes the organisations involved work with this single category, in order to strategically represent bioplastics as a single sector, and to include whoever might be interested in and benefit from their work. Sometimes, however, they prefer to use 'sub-categories', where more specific features are made relevant.

There are two main 'sub-categories' of bioplastics evident in my reading of *Bioplastics Magazine*: 'biobased' and 'biodegradable.' These terms define quite distinct features; one referring to the source of the material and the other referring to the disposal of the material. I mentioned briefly in the introduction that these terms themselves, and the criteria defining them, are subject to controversy. In this section I consider what is at stake regarding these sub-categories by exploring their development and changes to them. I show that these sub-categories get taken up differently by different actors and value systems, which in effect channels bioplastics' development in certain directions, as well as influencing the actors and values involved in the creation and development of bioplastics in return.

Biodegradable Bioplastics

I first focus on the sub-category 'biodegradable' bioplastics and its development through different regimes of composting and recycling infrastructures. Biodegradability was one of the first defining features of bioplastics as a new category. As mentioned earlier, the industry association today called the European Bioplastics Association was formerly named IBAW (Interessengemeinschaft Biologisch Abbaubare Werkstoffe – Industrial Working Group for Biologically Degradable Plastics). Biodegradability as a quality is mobilised as a solution mostly in areas to do with waste problems, and often rather than being characterised as 'biodegradable' this quality is visible as 'compostable.'

Indeed, composting facilities became one of the influential stakeholders in the field, and arguably the subcategory biodegradable was made possible and developed through social and technical arrangements of composting infrastructures. In the 1980s, municipalities were considering alternative ways of managing waste, as evidence of the negative effects of incineration and landfills had been published, and composting facilities started to appear on the waste management scene.[66] This was the composting infrastructure that was in place in the 1990s, within which biodegradability was 'qualified' (see Callon and Muniesa, 2005) as compostability.

---

[66] *Bioplastics Magazine* 03/2007, 'Industrial Composting: An Introduction', article contributed by Bruno De Wilde, from Organic Waste Systems, Belgium.

In return, biodegradable plastics have changed composting procedures and concepts of efficiency as well. *Bioplastics Magazine* has published a report showing that bioplastics are actually ‘good’ for composting facilities.[67] As explained in this report, biodegradable plastics could increase the amount of compostable content in that, for example, catering waste can now be composted. As catering waste is a mix of organic food waste and plastic, previously it could not be composted or recycled, as the compost or the recycling process would be contaminated. Separating the food waste from the plastic was a costly and, therefore, unfeasible process. Also this report explains that biodegradable plastics made the aeration of the compost easier due to the decreased density of the waste. Thus, adding biodegradable plastics into the compost heap would result in better quality compost, due to the improved carbon/nitrogen ratio, and this would also mean that the odour control would be easier. As such, biodegradable bioplastics also redefined compostable materiality within the economies of current sociotechnical arrangements. In this way biodegradable bioplastics are rendered valuable for the composting process, and influence the composting practices and infrastructures that gave rise to it. Further practices related to collecting catering waste and ways of involving these mixed waste streams in the composting infrastructure are reproduced, in that this waste has to be collected separately and sent to composting facilities.

The close relation of bioplastics to composting organisations is also informing general discussions on what to include in the category. I have mentioned earlier that *Bioplastics Magazine* distinguishes bioplastics from a type of material categorised by the magazine as

[67] *Bioplastics Magazine* 03/2007, ‘Industrial Composting: An Introduction’, article contributed by Bruno De Wilde, from Organic Waste Systems, Belgium.

oxo-degradables. As explained earlier, oxo-degradables are, by all appearances, similar to biodegradables. However, at the molecular level the carbon chains are left intact, and microorganisms cannot digest them. Clearly oxo-degradables are a kind of material that would disrupt the composting process, and therefore are not desirable for the composting organisations.

Until biodegradability was standardised and certified it was simply impossible for the various users of biodegradable plastics to distinguish them from other plastics. I will turn to standards in the next section, but for now I want to focus on the ways in which the interests, and thus the definitions and usages of ‘biodegradable’ became so varied that the term itself became problematic. As reported in the magazine, some countries even decided to ban the use of the term biodegradable on certain applications to prevent misunderstandings.[68] Inevitably, banning the use of the term impaired the visibility and qualification, and arguably the development, of the sub-category of biodegradable.[69]

Biodegradability is also taken up as a negative feature by some groups, in that products are still used only once and materials and resources are used wastefully. The proponents of these kinds of arguments are the organisations and facilities that have been formed around recycling of traditional plastics, and that have established certain practices and routes for the

[68] *Bioplastics Magazine* 04/2007.

[69] Although I do not have enough data to verify this, the statistics referred to at the beginning of the next section that points to a stagnation of biodegradable plastics might be a data verifying my claim.

materials. These groups claim that recycling is a more environmentally friendly approach to material sources.[70] Interest in the recyclability of bioplastics followed:

> *Collecting industrial and post consumer waste of polylactic acid (PLA), for instance, and converting it back to lactic acid by depolymerisation results again in a purified base material for the polylactic acid production. In doing so, corn production, corn wet milling and fermentation could be avoided and leading to an overall reduction of costs and energy consumption.*[71]

As a result, the recyclability of bioplastics became a topic of concern where bioplastics were *channelled* towards being recyclable, or certain types of bioplastics, such as PLA, which can be recycled, became of interest to these other groups.

Multiple groups interacting with bioplastics required that means be developed that would allow actors to distinguish bioplastics from other materials. Labelling is one way of doing this. However, currently, some waste management and recycling facilities use infrared recognition technology to sort out different types of plastics such as PET – water bottles, or HDPE – milk bottles. This meant that bioplastics had to become distinguishable in these networks, or the existing system made compatible with the new materials.

---

[70] *Bioplastics Magazine* 04/2007. 'Biopolymers as an option for sustainability – Quo vadis?' article contributed by Miriam Wehrli, Project Manager and Dr. Markus A. Meier, Head Market Platform Packaging Market Platform Packaging, at Ciba Inc., Switzerland.

[71] *Bioplastics Magazine* 04/2007. 'Biopolymers as an option for sustainability – Quo vadis?' article contributed by Miriam Wehrli, Project Manager and Dr. Markus A. Meier, Head Market Platform Packaging Market Platform Packaging, at Ciba Inc., Switzerland.

In this section I have introduced the controversies around biodegradability, how it is calculated differently within different arrangements, and how certain concerns channel the development of bioplastics in certain directions. I turn next to look at the shift in sub-categories and changing definitions and valuations of biobased bioplastics, and how this *channels* the development of bioplastics in certain directions.

Biobased Bioplastics

After 2010 the biobased category became more prominent. The statistics from Nova Institute show that it is projected that in 2018 the biobased bioplastic production will be 5,605 metric tonnes, whereas biodegradable bioplastics will remain at 1,126 metric tonnes.[72] In my interview, Thielen, the editor of *Bioplastics Magazine,* stated:

> *Today, in many countries, the 'biobased' aspect is much more important than the 'biodegradable' aspect. The biodegradability is not so much the most important thing anymore.*

In addition, when the name of IBAW was changed to European Bioplastics Association, the new scope of the association was defined as dealing with 'not only with biodegradable polymer products […] but also with those that are non-biodegradable but based on renewable materials.'[73] This clarification of the scope of the association shows that in the beginnings the

---

[72] 'Bio-based Building Blocks and Polymers in the World' pdf accessed from www.bio-based.eu/markets on 20th Aug 2015.

[73] *Bioplastics Magazine*, 01/2006, section 'News', 'Plastics database now includes bioplastics', by Michael Thielen.

focus was on biodegradability and later this emphasis shifted, to cover biobased bioplastics as well. However it is notable that the term biobased was not established yet, the term 'renewable material' is used. Similarly in the first issue of the *Bioplastics Magazine* bioplastics were defined as plastics 'which are A) based on (annually) renewable raw materials (RRM) or B) biodegradable.'[74]

The editorial note of the 41st issue re-defines the scope of the magazine:

> *Bioplastics Magazine is more and more trying to look out of the box or – put another way – to open our scope of topics from pure bioplastics more towards biobased building blocks and other applications, in the sense of green or biobased chemistry.*[75]

In sum, the definitions offered in the magazine make evident that what started only as biodegradables became bioplastics, the scope of the latter was broadened to encompass biobased plastics as well, and now the quality biobased is prominent and includes not only plastics but other biobased materials.

This shift can be explained in several ways. As Thielen states, rising oil prices and the realisation that oil is a limited source resulted in a search for alternatives to oil. Moreover, the scope of biobased, in terms of the mobilisation of environmental issues, seems to be broader

---

[74] *Bioplastics Magazine* 01/2006, section 'Basics', 'Definition of "Bioplastics"', by Michael Thielen.

[75] *Bioplastics Magazine* 05/2013, 'Editorial', by Michael Thielen.

– from carbon footprints to environmental friendliness, from sustainability to climate change. Additionally, global companies have expressed an interest in biobased plastics. The joint investment of Coca-Cola, Heinz and some other large companies to produce packaging bottles from biobased bioplastics, since 2005, resulted in the production of 30% biobased (but not biodegradable) coke and ketchup bottles.[76] Also, plastics giants such as Braskem and Dow started producing Polyethylene and Polypropylene from biobased bio-ethanol.[77] These large scale companies, with their high volume production in biobased bioplastics, inevitably became influential players in the field.

At the same time, the biobased category is also taken up by actors for whom it is associated with negative values. As reported in the magazine 'there is an ongoing public, political and industrial debate, with wide-reaching implications, on the competition between food, animal feeds and industrial markets for agricultural raw materials.'[78] As Thielen explains, human rights organisations are framing it as an 'ethical' issue that plant sources are used to make consumer goods. Thielen states in my interview that: '[They] say, "hey! we cannot make drinking cups like this out of corn, while people in other countries are starving because they do not have enough to eat".' The magazine replies to these discussions in several ways. As stated in a

---

[76] *Bioplastics Magazine* 03/2009. 'Coca-Cola Introduces Bottle Made From Renewable, Plant-Based, Recyclable Plastic', by Michael Thielen.

[77] *Bioplastics Magazine* 04/2009, 'Land Use for Bioplastics', article contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

[78] *Bioplastics Magazine* 04/2009, 'Land Use for Bioplastics', article contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

report in the magazine, 'people have been using agricultural raw materials for energy and materials as long as mankind has been on the earth.'[79] In the same issue it is also argued that 'the main reasons for hunger are distribution, logistics and financial resources.'[80] In addition, the magazine proposes that unused land can be employed to produce crops for bio-materials, which would also provide additional income to many farmers.[81] The magazine defends bioplastics by stating that the additional impact of bioplastics on food markets is extremely small. A report in the magazine referring to the website of NatureWorks states that 'approximately 2.5 kg of corn (15% moisture) are required per kg of PLA.'[82] This, according to the magazine, is equal to 0.7 % of the agricultural crop land worldwide or '50 percent of the European set-aside zones – which are not even being used for food production', based on the calculations for an envisioned 10% bioplastics share in the plastics industry.[83] In another issue, the magazine explains with other statistics that the effect of bioplastics in the food market is 'negligible', by comparing it with the biofuels market. The impact of biofuels on

---

[79] *Bioplastics Magazine* 04/2009, 'Land Use for Bioplastics', article contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

[80] *Bioplastics Magazine*, 2009/4, 'Land Use for Bioplastics', article contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

[81] *Bioplastics Magazine* 04/2009, 'Land Use for Bioplastics', article contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

[82] *Bioplastics Magazine* 02/2007, 'Bioplastics vs. Agricultural Land', by Michael Thielen.

[83] *Bioplastics Magazine* 02/2007, 'Bioplastics vs. Agricultural Land', by Michael Thielen.

food markets is calculated to be 250 times more than bioplastics, which equals an effect of only 0.1%.[84]

These valuations, in effect, *channel* bioplastics' development to non-food sources. For example, as reported in the magazine the German automotive industry has decided not to use 'potential foodstuffs such as sugar, starch or edible oil' for bioplastics production.[85] Also the magazine announces it as a 'relief' that there are also developments under way to produce bioplastics from 'secondary biomaterial such as straw, stems and leaves, and even from municipal waste water.'[86] My interviews with various material producers also revealed that the development plans of these companies were directed towards other feed stocks rather than plant sources, as such a source might be mobilised in controversial discourses.

In other cases, rendering bioplastics as biobased, and made of plant sources, involves them in crop production networks, and so bioplastics are influenced by the visible issues and valuations in the agricultural sector and related groups. For example, the GMO discussion affects bioplastics, and bioplastics development is *channelled* in GMO-free directions where a new concept 'GMO-free-bioplastics' is produced. Marc Verbruggen, the CEO of NatureWorks, explains:

---

[84] *Bioplastics Magazine* 04/2009, 'Land Use for Bioplastics' article contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

[85] *Bioplastics Magazine* 04/2009, 'Land Use for Bioplastics' article contributed by Michael Carus and Stephan Piotrowski, from Nova-Institut GmbH, Germany.

[86] *Bioplastics Magazine* 02/2007, 'Bioplastics vs. Agricultural Land', by Michael Thielen.

> *…the French consumer does not seem to like genetically modified anything. […] So brands selling in France will always be concerned about genetically modified anything, so for those brands with those end users, selling in those particular countries, NatureWorks indeed offers a variety of certification schemes.*

Indeed NatureWorks offers three options regarding the source of its PLA, one of which is the 'GMO-free' option, the other option is being able to track the source, and the last option is the purchase of GMO-free corn to replace the corn used for the production of a particular product. In this case, the valuation and visibility of bioplastics as biobased involves the category in discussions about the methods of production of plant sources. As a result of the biobased category becoming visible, these valuations influence the category in return. And the valuations within food-source and GMO discussions direct the development of bioplastics.

4.3 Standardising and Certifying the Sub-categories

In this section I direct my attention to standards. Standards can simply be defined as the 'norms' or 'measure' for something (Busch, 2011). However, within the conceptualisation I have set out in the introduction of this chapter, I look at how standards are created and change with respect to the different interests of different actors. Here I draw on ideas from Cochoy (2005) and Busch (2011) to elaborate on issues to do with standards. These studies show me that the topic of standards is an immense one, so I necessarily narrow down my scope. I focus on how standards direct the making of bioplastics, and more specifically on the development of certain standards as they are defined in *Bioplastics Magazine* and by the certification organisations that award the compostable or biobased labels. This gives me an insight into the dynamics involved in the fields that are implicated in the making of bioplastics.

I argue that these standards and certifications for biodegradable and biobased *enable* these qualities, by bringing together the relevant actors and by maintaining these relations, as standards and certifications define who is related to whom and in what terms. I show that these standards are created within regional development plans and political priorities, and elaborate further on how the development of bioplastics is directed by these priorities. I also argue that these certification systems, especially the 'starred' biobased certificates, rather than only filtering and excluding certain materials, *encourage* development in certain directions.

In his account of the history of standards, and the intricate relations among standardisation, certification, and the creation and evolution of consumers, Cochoy (2005:41) explains that standards were 'the only agency that could reconcile the three contradictory interests of the law and the state, industry and civil society.' He states that standards came about as a result of contradictory interests of these relevant groups, and at the same time 'guaranteed the link between the involved parties' (Cochoy, 2005:48). He adds to this framing of standards by establishing the significance of certification, insofar as standards are 'slipped into' marketplace by certification and so involved as well in creating the 'customer consumer,' who could in turn change the markets and organisations. Cochoy (2005:42) explains the development of certification systems as follows:

> With certification, the nature of standardisation changed. It became a means of displaying certain product qualities and thus differentiating a particular product from competing ones.

In today's marketplace consumers are acquainted with standards and certification, and these have become means of making qualities visible. Certification organisations certify those materials (and products) that comply with the standard's specifications, on occasion according to the test methods specified in the standard. To exemplify this, I draw from one of my interviews with material producers. Francesco Degli Innocenti, the director of the group for Ecology of Products and Environmental Communication at Novamont, explains the significance of certification for Novamont:

> *Environmental communication is basically certification. So we communicate the characteristics of our products basically by means of certification, by means of statements that are based on standards.*

My interviews showed that standards and certificates are clearly important for consensus building among the related actors, as well as for communicating the quality of materials.

Certification bodies, such as DIN CERTO and Vinçotte,[87] work separately than the standardisation organisations such as the American Society for Testing and Materials (ASTM) and The European Committee for Standardization (CEN). These certification bodies take the standards as the definitive guide and send the material samples to testing laboratories that the certification organisations define as 'objective' and 'independent.' The certification organisations award certification labels to be used only for three years, after which the certification has to be renewed. The certification label is accompanied with a unique reference number to allow 'traceability' of the products. During these three years, the certification

[87] DIN CERTO is a German and Vinçotte is a Belgian certification organisation.

organisations take samples from the market to test to see if they still comply with the requirements specified in the standards. Certification bodies in this sense work for the 'rights-endowed consumer', as termed by Cochoy (2005), to ensure that the brands' claims are true and that the consumers are not mislead by these brands.

I turn next to the specific standards used to certify the various qualities of bioplastics.

Standardising and Certifying Biodegradable Plastics

It is important from the outset to acknowledge that there are various national and international standards organisations that are engaged with setting specifications and test methods to define certain qualities. There are also a number of standards which cover a wide range of qualities related to the biodegradability of bioplastics, such as 'outdoor exposure testing of photodegradable plastics', 'anaerobic biodegradation of plastic materials under high-solids anaerobic-digestion conditions', 'the aerobic biodegradation in soil of plastic materials or residual plastic materials after composting', 'the biodegradation of plastic materials in the marine environment', and the like.[88]

The standards that are referred to in relation to biodegradability of bioplastics are as follows: For the US market; ASTM D6400 – Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities, and D6868 – Standard Specification for Labeling of End Items that Incorporate Plastics and Polymers as Coatings or Additives with Paper and Other Substrates Designed to be Aerobically Composted in

[88] Information accessed from www.astm.org on 14th Oct 2015.

Municipal or Industrial Facilities. And the European standards EN 13432, ‘requirements for packaging recoverable through composting and biodegradation' and EN 14995 covering all bioplastics (so not only packaging).

It is important to bear in mind that the sub-category biodegradability is qualified as ‘compostable’ in these cases, since biodegradability is qualified and defined within the composting infrastructure. Biodegradability and compostability refer to different conditions under which biodegradation takes place. Composting facilities have certain humidity and temperature conditions (although these tend to change among facilities and countries), and require biodegradation to take place within 90 days, for commercial reasons. So a biodegradable material which biodegrades in a year will be un-compostable in composting facilities. Although the terms biodegradable and compostable are used interchangeably even by the material producers, certification labels for composting precisely state the terms that are agreed on.

It is important to note that these standards do not define definitive or absolute criteria; rather, they change in time by the changing stakeholders and their power relations. For example, D6400 was first set in 1999, then revised in 2004 and in 2012.[89] I will elaborate on ASTM (American Society for Testing and Materials) standards on biodegradability to expand on this point. ASTM has a subcommittee, D20.96 to ‘respond to the demand’ that comes with the

[89] Information accessed from http://www.astm.org/Standards/D6400.htm on 9th Feb 2013.

increasing interests in biobased and biodegradable plastics.[90] The sub-committee D20.96 comprises 115 members from different countries and includes 'companies with a green focus', academic institutions, laboratories, and government organisations, including the 'US Army and Air Force and the state governments.'[91] This definition of the sub-committee D20.96 reveals that standards are made in negotiations through these variously influential stakeholders.

Moreover, the dynamics that bring these actors together can be various. For example, the EN standards on compostability are politically induced and enforced by legislation. These standards were developed in relation to the European Directive 94/62/EC, which 'obliges' by law that all the member states engage in efforts to prevent waste and promote the reuse of packaging waste.

The compostability of bioplastics is certified by certification organisations such as DIN CERTO, the Bioplastics Product Institute (BPI) and Vinçotte (see Figure 4.2). Vinçotte also has a non-standardised certification of 'home compost' which is awarded according to Vinçotte's own criteria, which suggests that certification systems can also act back on standardisation to settle controversies about certain issues, in this case about the diverse composting practices. These organisations ensure that the materials are tested according to the specifications in standards.

---

[90] Information accessed from http://www.astm.org/SNEWS/MJ_2009/quigley_mj09.html on 9th Feb 2013.

[91] Information accessed from http://www.astm.org/SNEWS/MJ_2009/quigley_mj09.html on 9th Feb 2013.

Figure 4.2 Compostability certification labels of Biodegradable Products Institute[92] and Vinçotte[93]

This section explored the different standards and certifications on compostability, and showed the political and environmental dynamics that inform standards and so definitions of bioplastics. Next I turn to the standards and certificates that define being biobased.

Standardising and Certifying Biobased Plastics

The only visible standard for biobased quality, according to my references, is ASTM D6866 – Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis, where the US Department of Agriculture (USDA) and Vinçotte award biobased certification labels to the materials (and products) that comply with ASTM D6866. In this section I will follow the story backwards, from certifications to standards, as the certification labels are self-revealing (see Figure 4.3) and show the political and

---

[92] Image derived from https://www.lifewithoutplastic.com/store/media/wysiwyg/third_party.jpg on 4th Dec 2015.

[93] Image derived from http://www.macplas.it/archivioFiles/tabarticoli/Vanetti%20041115.jpg on 4th Dec 2015.

practical dynamics of making standards (and so materials) and the ways in which these certifications *encourage*, rather than simply exclude.

Figure 4.3 Biobased quality certification labels of USDA[94] and Vinçotte[95]

The USDA label shows the stakes around this standard. USDA is clearly involved in this certification system. Moreover there is a small inscription 'FP', just next to the circular symbol that means the certified material (or product) is within the 'Federally Preferred' designated system. As such, this label directly reveals the political stakes around this standard and certification scheme. Indeed, this certification system was initiated by the federal procurement program, 'BioPreferred®', in correspondence with the 2002 Farm Bill (The Farm Security and Rural Investment Act of 2002) and the Agricultural Act of 2014.[96] BioPreferred® has the goal

---

[94] Image of USDA label, derived from http://www.environmentalleader.com/2013/07/12/usda-designates-new-biopreferred-categories/ on 14th Oct 2015.

[95] Image of Vinçotte label, derived from http://bio4life.nl/information/standards-certification/ on 7th Sept 2015.

[96] Information accessed from http://www.biopreferred.gov/BioPreferred/faces/pages/AboutBioPreferred.xh

‘to increase the purchase and use of biobased products.’[97] USDA was assigned as the ‘implementing agency’ and ASTM was assigned by USDA to develop the standard to be used in BioPreferred programme.[98] In my interviews, this interest in biobased products in the US is regarded within US regional development plans related to a political priority on non-oil-dependence.

The committee D20.96 within ASTM set D6866 in 2004. A brief look at the definition and considerations about this standard reveals that, next to political concerns, those involved in making the standards have to consider the social and technical organisation of the current standardisation, testing and certification infrastructure. For example, the report of ASTM on D6866 explains that the testing method has to be practical, accurate and safe, but it also has to fit the time frame expected from a certification process. So the standard specifies the ‘liquid scintillation counter technique’, and ‘particle acceleration technology’ as the test methods that are safe, as the testing of biobased content in the molecular level can be potentially dangerous as the molecules can combust, and so accurate even when small quantities are tested to be safer, and that will still give enough information about the whole of the product.[99]

Looking at the images of the certificate labels again we can see that the USDA label states the percentages of the biobased content (separately for the product and the packaging where

---

tml on 9th Sept 2015.

[97] Information accessed from http://www.biopreferred.gov/BioPreferred/faces/pages/AboutBioPreferred.xhtml on 9th Sept 2015.

[98] Information accessed from http://www.astm.org/SNEWS/MJ_2011/enright_mj11.html on 9th Sept 2015.

[99] Information accessed from http://www.astm.org/SNEWS/MJ_2011/enright_mj11.html on 9th Sept 2015.

applicable), and the Vinçotte label has four stars on the image. Vinçotte awards one 'star' to a product that has biobased content of 20-40%, two stars to 40-60%, three stars to 60-80% and four stars to 80% or more biobased content. It's helpful here to refer to Busch's (2011) four types of standards: 'Rank', 'Olympic standards', 'Filters' and 'Divisions.' Standards on bioplastics are 'filter' type standards, where instances above a certain threshold are all accepted within the category, whereas in the 'rank' type of standards there would be one winner. I realise, however, that the certifications on biobased do not exclude those below a threshold as in biodegradables – albeit a low biobased content, even if with one star, the material is still within the category. So, as I suggest, the certifications on biobased, rather than excluding materials according to the standards, *encourage* the materials to be *more* biobased.

4.4 A Twist in Standardising and Certifying: Certifying Products as Opposed to Materials

Although so far I have focused on the categories and standards of the material per se, in the market place what is certified with the labels 'compostable' or 'biobased' are the 'products' rather than the 'materials.' This appears as a tension point between materials and products in two senses. The first is a physical tension between the materials of a product that claim to meet certain standards and those that do not, and second a tension among the actors engaged in making bioplastics and those making the products. However, I show that this is a generative tension where materials and objects are co-constituted and reproduced.

First of all, 'products' are made of different components, in which each component might be made of different materials. For example, a simple salad packaging is composed of the container and the sealant transparent film lid. In this case, for the 'product' to be able to be labelled as ‘compostable’ both the container and the lid should be compostable. So when the container is made compostable, the lid also has to become compostable.[100] Although this appears as a tension between the different materials and the product they compose, it is a process in which materiality is reproduced, in that both the lid and the salad packaging become compostable, where materials and products co-constitute each other in the simplest sense of the idea of co-constitution.

Second, although a material might be compostable, a certain thickness in a packaging container or a product might not be compostable.[101] The BioPreferred programme, mentioned above, has the list of approved specific ‘products’ such as NatureWorks biopolymer DeliCombo Boxes & Lids, and NatureWorks biopolymer Sushi Trays & Lids, from the company Excellent Packaging and Supply,[102] since due to the thickness of material, the end product might not comply with the standards.

Moreover, bioplastics products are not made possible only according to the standards and certifications on biodegradability and biobased. Standards on agricultural production, packaging or other domains get involved in certifying bioplastic products. For example, food packaging has to comply with standards of Food Contact Approval (FDA, defines the safety of materials that can be in contact with food items) or regulations about the hygiene conditions regarding preparation and packing of the food itself, such as pasteurised products that

---

[100] Example provided in my interview with Andy Sweetman, Innovia on 15th Aug 2014.

[101] Example provided in my interview with Andy Sweetman, Innovia, on 15th Aug 2014.

[102] Information accessed from http://www.biopreferred.gov/BioPreferred/faces/catalog/Catalog.xhtml on 9thSept 2015.

require heat setting. I note here that any one material-product will be enacted through these multiple relations, but leave the detailing of the relevant actors, dynamics, standards and certifications as they come into relation to the examples that follow in the remaining chapters of the thesis.

4.5 Conclusion: The Emerging and Changing Categories and Standards of Bioplastics

This chapter has shown that bioplastics is a multiple field, in terms of the variety of the actors, interests and sociotechnical arrangements that are involved. The actors range from government agencies to resin producers, from farmers to activist groups. And the dynamics through which they came together range from political legislative obligations to environmental concerns. We have also seen that definitions, categories and standards pertaining to bioplastics and their valuation are slippery, dynamic and relative to the interests at stake. I showed that bioplastics are partly made in and through these changing and shifting categories, where the various actors *negotiate* the value of bioplastics.

The detailed exploration of sub-categories showed how categories relate to and develop through distinct practices, such as the relation between composting infrastructures and biodegradable plastics. The analysis of the ways in which categories carry values showed that categories are both symbolic and material, and result in both symbolic and material opportunities. They reproduce materiality and practices, as well as values. As such, categorising and standardising *channel* and *encourage* the development of bioplastics in certain directions.

Looking at categories and standards as created and changing suggests that they are means with which to build consensus among different actors, by defining who is involved in what terms, as well as by maintaining these relationships. Exploring standards and certifications in more detail showed that standards are used to define materials. However, certificates are awarded not to materials but to end products. As such, all aspects of the end product also have to comply with the relevant standards.

As well as demonstrating the wide scope and multiplicity of bioplastics, this analysis provides insight into the making of materials, in that categories and standards, understood to define materials objectively and scientifically, are socially and technically made. This is the case insofar as materials are *negotiated*, *channelled and encouraged in particular directions* by the interested actors, involved both in making the broad categories of standards, and also in the making of specific material-products.

CHAPTER 5

PRODUCING BIOPLASTICS:

ELABORATING SPECIFIC QUALITIES

Just because it is green doesn't mean anything. It must work technically. So technical performance is critical.

Andy Sweetman, Global Marketing Manager, Innovia,
and former chair of the European Bioplastics Association
Quotation from my interview on 26th June 2014.

The previous chapter examined the making of the generic category 'bioplastics' and the standardised sub-categories 'biobased' and 'biodegradable.' I explored how the categories are created and are changing as a result of the different economic, environmental, organisational, political, and infrastructural interests of different actors, different industries, NGOs, and governments. The previous chapter, thus, provided insight into the positioning and valuing of materials in generic categories.

The current chapter takes a different perspective on the making of materials and concerns itself with the 'physical production' of bioplastics. Arguably physical production, especially the transformation of materials into products, is also one of the places where material-product relationships are formed. These processes might at first sight appear to be purely technical and straight-forward matters. However, I want to refer back to my conceptualisation of ‘substitution’ in Chapter 2. As I have argued, substituting is not simply a question of replacing one material with another as a result of innovation, but it also entails symbolic and social processes in which materials are compared to each other and to existing infrastructures, and through which materials are ‘calculated’, using Callon et al.’s (2002) term. By calculation, Callon refers to the complex processes through which the value of the qualities of a good are stabilised as well as challenged. By exploring the physical production of bioplastic materials with reference to my conceptualisation of substitution, in this chapter I analyse the multiple social, as well as technical, processes in and through which the specific qualities of materials are elaborated.

In this chapter, I take the perspective of the material producers and draw on my interviews with representatives of five leading bioplastics producers: NatureWorks, Clarifoil, Innovia, Novamont and Biome,[103] all of which manufacture the ‘plastic granules’ or films that are then turned into products by various processors. As my interviews revealed, material producers often monitor and guide the whole process of production up to the realisation of the product. This close involvement may be a feature of a new industry in which new relations between actors are being formed, and in which material producers are keen to make sure their materials work well in practice, and successfully substitute for those materials that they replace. Without this involvement, as my respondents explained, product manufacturers are

[103] I conducted interviews with the president and CEO of NatureWorks- Marc Verbruggen, the CEO of Biome- Paul Mines, the Global Marketing Director of Innovia- Andy Sweetman, the Director of the Ecology of Products and Environmental Communication of Novamont- Francesco Degli Innocenti and the Marketing Representative of Clarifoil- Sasha Herriot.

hesitant to feed a new and unknown material into the production equipment in which they have invested. Speaking with materials producers therefore provided me with a broad view of the processes involved. In addition my sample included representatives from a good range of companies involved in various production processes and markets.[104]

In this chapter, firstly (Section 5.1), I expand on the theoretical background that allows me to explore the substitution of materials and to see qualities of materials as elaborated in these multiple processes. I argue that materials and their qualities are *always* elaborated in relation to products. This insight structures the rest of the chapter.

I then (Section 5.2), focus on three instances of substitution: the first, when a material is replaced in a ‘product’, the second, when there is some replacement in the ‘production’ process, and the third, where I focus on the implications of replacement in ‘further production arrangements.’ I organise the section in three parts accordingly. Although this chapter is informed by a variety of examples that materials producers provided me with, to make it easier for the reader to follow the technical processes and details, I exemplify my analysis with reference to one main case: Ingeo®, concentrating especially on a specific grade of Ingeo, 7032D, and its application in making bottles. Ingeo is the trademarked material of NatureWorks, one of the first bioplastics producers. In the first part (5.2.1), which focuses on replacing materials in a ‘product’, I compare two different product applications of Ingeo 7032D – ‘Ingeo bottle’ and ‘Ingeo clamshell packaging’ – and show that the same property of

[104] In Chapter 3, I have shown that these materials producers produce very different materials which go through different production processes, and are made into very different products. This meant that the relations and the processes in and through which these materials are substituted and come to be present a fruitful variety for exploring substitution through this sample of materials producers.

a material is differently relevant and valuable for these different products. This comparison leads to two conclusions about the ways in which the qualities of materials are elaborated. I show that the qualities of the new material are elaborated partly in relation to the established conventions of performance – including aesthetic and practical features of the product. And the second conclusion is that the qualities of new materials are partly elaborated in relation to the qualities of previous materials out of which the product has been made. In the next part (5.2.2), I move on to consider substitution in the 'production' of the Ingeo bottle. I show that new qualities of Ingeo are elaborated in relation to the specific production route of the product. In the last part of the section (5.2.3), I explore the 'further production' processes through which the material-product couples travel, such as the process of putting contents into the packaging and sealing the pack.

This analysis allows me to highlight some general insights about the making of the material and the nature of the material-product relationships (Section 5.3). Specifically, I argue that materials are *specialised* in the making, where different actors, with different organisational, infrastructural and economic motives, *compromise* on certain qualities. In addition, my analysis of physical production processes shows that thinking of materials always in relation to the technical and social arrangements of the specific material-product combinations provides a better understanding of material production, as compared with methods that view production as purely technical or isolated from the established social and technical traditions, and abstracted from the specific product into which the material is formed.

5.1 Producing Materials and their Qualities

In this section I expand on the theoretical background outlined in Chapter 2. I draw on the ideas of Hawkins (2013a) – especially on the notion that the qualities of materials are elaborated, and go on to argue that bioplastic materials are *always* oriented to products in their physical production. I expand on and specify this analysis in more detail in the rest of the chapter.

I start by drawing on Hawkins' (2013a) chapter titled: 'Made to be Wasted: PET and Topologies of Disposability', in which she explores a particular quality of PET, namely its disposability. This study provides a useful framework through which to understand the production of bioplastics as well. For Hawkins (2013a:49) plastics' economic value has to be 'elaborated and produced' and she suggests that 'the economic capacities of plastic emerge in specific arrangements and processes, in which the material interacts with any number of other devices – human and non-human – to become valuable' (Hawkins, 2013a:49).

Hawkins' conceptualisation of qualities as 'elaborated' originates from Callon and Muniesa's (2005) idea of 'calculation.' As explained in Chapter 2, Callon and Muniesa's (2005) and Callon et al.'s (2002) accounts of quality and value of goods in market places relativizes the qualities of goods. They use the term 'calculation' to refer to the varied processes through which the value of products are defined in the complicated market environment of ambiguous situations and conflicting interests.

Moreover, Hawkins (2013a:50) states that the qualities of goods 'are never fixed; instead they are continually being enacted in multiple networks and interactions.' She demonstrates how the disposability of PET is calculated differently in different markets, and argues that the disposability of PET 'is continually being *re*qualified in the different arrangements and economies in which it is caught up' (Hawkins, 2013a:51). In her exploration of the different calculations of the disposability of PET, Hawkins (2013a:50) states that 'the qualities and calculability of goods are continually subject to change as they move through various assemblages from design to production to consumption and more.' This prompts me to see the physical production of bioplastics as one such series of assemblages through which qualities of bioplastics are elaborated, and as an outcome of bioplastics' interaction with various producers, production equipment and social and technical infrastructure of production. I do not follow a single specific quality into different arrangements, as Hawkins does, but using her arguments I examine how qualities of bioplastics are elaborated in different arrangements of bioplastics and products.

My analysis shows that bioplastics' arrangements are always in relation to a 'product.' By this I mean that bioplastics are always judged and positioned in terms of the symbolic, material and technical qualities of the product. My analysis reveals that materials producers do not think of bioplastics in isolation, detached from their social and technical environment. Rather, bioplastics are *always* developed and accomplished in relation to a 'product' application, and its production route. In the case of Innovia this link is the most salient, as Innovia only supplies bioplastics to the packaging industry. In this case, the material that comes out in a film format is either already *the* packaging product, or is sent to successive processors to be manufactured – cut and printed – into a more elaborate type of packaging.

Nevertheless, as my interviews revealed, other materials producers, who do not supply only one fixed sector, also focus on specific products and production routes. For example, NatureWorks *always* envisages its bioplastic material in a product. As one of the first materials producers in the field, when asked about the history of the field of bioplastics, Marc Verbruggen, the CEO of NatureWorks, replied:

> *If I go back in time, and let's use 2003 as the starting point, because 2003 is when we actually built the large plant in Nebraska and therefore we had a lot of product to sell, what you see there is that originally, I mean one of the first things you need to do is try to find the appropriate application for your product [here product stands for the product of NatureWorks, which is actually the bioplastic material].*

Verbruggen explains that the first step in making and developing a material is to find an 'appropriate application.' The discourse of the materials producers, in which bioplastics are referred to as 'the product' and what others would recognise as the end-product as 'the application' is suggestive on its own. First of all, according to the materials producers end-products are 'applications' of materials. So they are still materials, but are 'applied' to different usages. As such, rather than two separate units as 'material' and 'product', products are materials put to use for a cause, hence the relationship between materials and products is that of 'application' rather than 'transformation.' Having noted this point, I stick to my own terminology, using an ordinary consumer's distinction between a product (for example, a bottle) and a material (of which the bottle is made). I continue my analysis in these terms.

Materials producers organise research and development with reference to specific sectors and sites of application. Verbruggen mentions:

> *We are organized in market segments. And I think we have 6 or 7 global market segments. And the reason why we are organized that way is that is*

very specific knowledge about the certain market segment. So we have experts for example in film, yeah? And that expertise is very different than the expertise you need in durable goods or in food service or than you need in nonwovens [...] that's why we have specialists, application specialists, not PLA[105] specialists, for a lot of different applications, and they can then test, judge whether or not that particular application makes sense.

In this case, market segments refer to specific product areas such as, film, durable goods, and food service. Within this segmentation, Verbruggen stresses 'the application specialists' as opposed to 'PLA material specialists.' Similarly, in 2009, NatureWorks opened an 'applications lab', investing $1 million.[106] The lab is intended for 'developing and testing compounds on commercial machines, moving Ingeo natural plastic into new product areas, demonstrating Ingeo processing characteristics to converters and working side by side with brand owners to test their product concepts.'[107] Setting up an applications lab, where materials are internally tested in relation to product and product production routes, shows that materials are developed to become certain products and are tested in various ways in comparison to existing material-product arrangements.

---

[105] PLA is abbreviated from Poly Lactic Acid that is the family name of a certain type of bioplastics. PLA is a new plastics in its chemical composition, so it has a unique family name, such as Polyethylene Terephthalate (PET) and polypropylene (PP), which are the types of plastics that are more commonly known.

[106] Accessed from http://www.natureworksllc.com/News-and-Events/Press-Releases/2009/04-22-09-Applications%20Lab on 2nd March 2015.

[107] Stated by Marc Verbruggen in the report accessed from http://www.natureworksllc.com/News-and-Events/Press-Releases/2009/04-22-09-Applications%20Lab on 2nd March 2015.

This relation carries through to the detailed modifying and adjusting of material formulations as far as possible. Verbruggen's explanation is revealing in this sense:

> *One thing you need to do is find the right applications and fine-tune the properties of your product to those particular applications.*

This quotation shows that materials are modified or 'fine-tuned' in orientation to specific products. Here, I want to bring into play the concept of 'informed materials' introduced by Bensaude-Vincent and Stengers (1996). In their book, *A History of Chemistry*, Bensaude-Vincent and Stengers suggest that materials contain information about their environment, such that context is not external to the molecules, but is constitutive of them. According to Bensaude-Vincent and Stengers (1996), materials are 'informed' by their environment in that chemical substances, laboratories, test schemes, intellectual property rights and interests of companies influence each other. Adopting Bensaude-Vincent and Stengers' idea I see that bioplastic materials are informed by brands, product performance requirements, and production arrangements, and that they are fine-tuned accordingly.

In what follows, I examine how bioplastics substitute for other materials and how specific qualities are elaborated in relation to particular products and to the established social and technical arrangements that are constitutive of bioplastics.

5.2 Elaborating Qualities of Materials: Substituting with Ingeo

In this section, I use the case of one particular grade of NatureWorks' Ingeo, 'grade 7032D' and a particular product, the 'bottle,' to expand on the argument that bioplastic materials are always oriented to products.

By way of reminder, NatureWorks is a materials producer, which ‘is the first to offer a family of commercially available biopolymers derived from 100 percent annually renewable resources with cost and performance that compete with petroleum-based packaging materials and fibres.’[108] With a production capacity of 160 tonnes a year,[109] NatureWorks holds 90% of the total PLA[110] production in the world market today, as Marc Verbruggen, the CEO, explains: ‘Then, we're, by far, the largest player and we really don't have any competitors.’ However, as I have explained earlier the category bioplastics does not have a single definition. As Verbruggen goes on to explain, if the bioplastics market is defined as ‘the new-to-the-world plastics, which is PLA and also products like PBAT, PHA, and PBS,’ then NatureWorks’ market share is about 80-85% of the whole market. If the ‘drop-ins’[111] are also included in the category, then the market share of NatureWorks is about 40-50%. These numbers place NatureWorks as the largest materials producer in the field, as well as one of the most influential.

Currently, NatureWorks has an established portfolio of volume production. However, in this section I focus on the bottles, which were considered to be a promising application area,

---

[108] Information accessed from http://www.natureworksllc.com/About-NatureWorks on 5th Feb 2015.

[109] Information accessed from http://www.natureworksllc.com on 5th Feb 2015.

[110] PLA is a type of bioplastics and NatureWorks material Ingeo is a type of PLA as well.

[111] Drop-ins biobased version of traditional plastics, such as BioPET and BioPP. So these materials have the same formulation as traditional PET and PP, but are sourced from biomass, as opposed to petroleum.

between 2003 and 2008.[112] A lot of investment went into realising PLA bottles. There are also practical reasons to focus on the bottles. First of all, bottles are a familiar product group and their production details are relatively simple to grasp. Plastic bottle making is an established industry, with social and material traditions, well established material-product relationships, and acquired wisdom about what consumers expect from a bottled product. Also, as one of the oldest, and actually unsuccessful 'applications' of bioplastics, in that this application is not popular anymore and the investment did not continue for various reasons, there is plenty of information, documentation, factsheets, datasheets, and reports on bottles and Ingeo 7032D, as well as my interview data, which provides me with means to explore this case in depth.

NatureWorks' Ingeo®, 'is a unique bio-based material made from plants instead of oil.'[113] Ingeo is supplied in granule format, where tiny plastic beads are melted and moulded by processors as they are transformed into products (see Figure 5.1 below). There are about 20 different grades of Ingeo, each of which has different qualities. The different grades of Ingeo can be made into products varying from durable car parts to disposable food packaging.

---

[112] In 2007 the '1st PLA Bottle Conference' was held (*Bioplastics Magazine*, 2007/1) which arguably shows the growing interest into bottle applications and the effort of *Bioplastics Magazine* to make a bioplastic bottle sector.

[113] Information accessed from the NatureWorks website on the booklet downloaded from http://www.nature worksllc.com/~/media/News_and_Events/NatureWorks_TheIngeoJourney_pdf.pdf on 20th March 2014.

Figure 5.1 Plastic granules[114]

Ingeo 7032D is apparently the grade specialised for bottle applications. The definition of this particular grade is as follows:

> *Ingeo biopolymer 7032D is a <u>bottle grade</u> resin designed <u>for injection stretch blow molded</u> applications <u>where heat setting is needed</u>.[115] [Underlined my emphasis]*

This definition points to three different instances of substitution and so to different actors and arrangements through which the qualities of Ingeo are enacted. A first step is to imagine that Ingeo can perform as a bottle for the end consumer. A second step is to suggest that the

[114] Image accessed from http://www.textiles-techniques.com/en/product/spunbonded-pla/ on 20th Oct 2015.

[115] 'Ingeo™ Biopolymer 7032D Technical Data Sheet Injection Stretch Blow Molded Bottles' is downloaded from NatureWorks' website on 24thFeb 2015.

material will be suited to the social and technical organisation of ‘injection stretch blow moulding’ processes. In addition, the product has to endure high temperatures (referred to as heat setting in the definition above) at the point when the bottle is filled.

These instances of substitution interact with each other and are indicative of the processes, dynamics, relations and human and non-human arrangements in and through which specific qualities of bioplastics are elaborated by differently interested actors.

5.2.1 Substituting PET with Ingeo in Water Bottles

Ingeo Water Bottles

One of the first products to have been made from Ingeo bioplastic is a water bottle. The first Ingeo bottles were commercialised between the years 2005-2007, by the brands Ihrplatz, Germany, and Biota, US.[116] To review this history, glass bottles or cans dominated the packaging market before plastics took over (Fenichell, 1996). PET has become one of the first plastics to be used in water bottles, and most water bottles have been made of PET since the 1970s (Fenichell, 1996). PET is used to bottle various other liquids as well, such as beverages, dairy products and household cleaning products. So, Ingeo water bottles emerged in a context in which thermosetting[117] plastics were already used for making bottles.

---

[116] *Bioplastics Magazine*, 2007/2 ‘Five PLA bottle pioneers’, by Michael Thielen.

[117] Thermosetting plastics are the group of plastics that get hard when heated and these plastics cannot be reheated to shape again.

Figure 5.2 Biota Water Bottle made of Ingeo[118]

The PET bottle, as a 'material-product combination', was valued and preferred to aluminium cans for its transparency – thus showing the contents. The PET bottle is flexible to a degree, so the bottle does not break easily. As such, the qualities of PET for bottles were superior to glass, in that both materials had equal visual qualities, but PET was more unbreakable so durable, and was less heavy. PET has been valued for its less permeable molecular structure and being inert to chemicals, both features that provide favourable barrier properties for

[118] Image accessed from http://biotaspringwater.com/files/Stubby_RGB.jpg on 14th Sept 2015.

bottling liquids, meaning that the contents of the bottle is not contaminated by the atmosphere outside the bottle.

Ingeo, if it is to be made valuable, has to be compared to PET. This is evident in my interviews and in various reports, datasheets, facts sheets of NatureWorks, and in reports in *Bioplastics Magazine*, which are based on comparative laboratory tests between Ingeo and PET. When two materials are compared, the point is to determine which one is the 'better' with respect to certain pre-defined qualities.

Verbruggen explains how the quality of 'permeability' of Ingeo is elaborated in relation to PET in terms of the performance of the bottle: in this case Ingeo is found to be 'worse' than PET:

> *In water bottles or carbonated drinks, you want very very high barrier properties. And there if you compare PET barrier properties with PLA barrier properties, PET is superior [...] all the other properties of PLA were very good, that one particular property, barrier property where PET is significantly better [...] Although we have a very nice water bottle market, especially in Europe, I think we will never be able to compete with PET on a global scale for that particular application.*

Barrier properties depend on the permeability of the bioplastic molecules, which is the term that is used to describe the resistance of the molecular composition to carbon dioxide and oxygen. However, the fact that barrier properties are 'worse' or even barely sufficient does not mean a product is not going to be made of bioplastics. As Verbruggen explains, there is still a niche market for Ingeo water bottles. There is a tension in terms of what the materials are capable of and the anticipated product performance. However, the product is nonetheless made of bioplastics, because other green qualities appear to be more relevant in this particular case.

The significance of the 'barrier property' also depends on the intended contents of the bottle. For example, barrier properties are sometimes not good enough for beverages other than water. NatureWorks has prepared reports on tests comparing barrier qualities between PET and Ingeo. For example, one such report compares Ingeo, PET and glass bottles used for storing osmotic filtered water kept at 37.8°C for 3 and 6 weeks periods: in terms of flavour and contamination these materials performed similarly.[119] This report further compares PET and Ingeo in cases where spring water, milk, salad oil and orange juice are stored under specified conditions and for fixed periods of time. Again no significant difference was found between these materials regarding microbial activity, taste and contamination.

The qualities of high 'gloss' and 'transparency' are elaborated as positive qualities for water bottles. A *Bioplastics Magazine* report on the brand, Blue Lake Citrus, which switched to Ingeo bottles, states that Ingeo bottles provide a 'clarity' comparable to the company's previous PET bottle, as well as a sufficient 'oxygen barrier' for the 60 days shelf life.[120] The

---

[119] Report on NatureWorks' website that refers to the study of Michigan State University-School of Packaging, accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Flavor_pdf.pdf on 10th Feb 2015.

[120] *Bioplastics Magazine*, 2007/2, 'PLA bottle is used for a Noble cause', by Michael Thielen.

quality of ‘stiffness’ of the material is also relevant for the bottles, but contrary to expectations it is a negative value, since it means that the bottle is easy to break.[121]

Next to these qualities of technical performance there are also aesthetic qualities that become relevant for the brands in terms of marketing products. In the reports in *Bioplastics Magazine*, PLA and PET bottles are also compared in terms of shape, size, and colour.[122] I use examples provided by Andy Sweetman, from Innovia, who has experience of the packaging sector and of accepted conventions about how product should be presented. For example, Sweetman explains that in the packaging of baby diapers, materials that are soft to the touch are preferred, rather than more dimensionally stable and crispy materials. By contrast, for crisp packs, it is preferred to have a crispy material, as customers associate it better with the crispiness of the contents.

These are some of the qualities of Ingeo that are elaborated in relation to PET and glass bottles, often with reference to accepted ideas within the industry about the performance of the bottles and about what the consumers want and are used to. The examples in this section suggest that materials are still compared as materials (so not in relation to products), but the qualities that are compared and are of value are elaborated in ways that depend on the anticipated product and related dimensions of performance, as well as visual and haptic qualities.

---

[121] *Bioplastics Magazine* 2007/2, the report on Biopearls R.O.J. Jongboom Holding B.V., The Netherlands.

[122] *Bioplastics Magazine* 2007/2, ‘Five PLA bottle pioneers’, by Michael Thielen.

Ingeo Clamshell Packaging

According to Verbruggen, one of the first successful applications of Ingeo produced on a large scale was the 'clamshell fresh food packaging', used to pack fresh berries and fruits. Clamshell packaging is used for a variety of purposes, from storing fittings to food items. Currently clamshells are made of a variety of materials; paper, and various types of traditional plastics, such as polystyrene, polyester, PVC, and mostly PET. For clamshell food packaging, Ingeo is, again, mostly compared to PET. However, in this case the properties of Ingeo and PET are differently relevant and valuable compared to the qualities that are important for bottles.

Figure 5.3 Ingeo Clamshell Container[123]

[123] Image accessed from http://biomasspackagingstore.com/seeshell-small-deep-hinged-clamshell-6-x-6-x-3.aspx on 8th Feb 2015.

Verbruggen explains:

> *[In] packaging of food, packaging of vegetables, whether in rigid or in flexible containers, what became clear in this case is that the competition of PLA was again PET. But of course in this particular application, the barrier properties are far less important. Actually, it works the other way around, in order to get food and vegetables fresh; it is actually good to have lower barrier properties so that there is more connection with the outside atmosphere.*

In her account of the disposability of PET, Hawkins (2013a:54) explains that 'the emergence of the PET bottle represented new material information about molecules and the multiplication of association between them.' Similarly, for the PLA bottles, new material information about bioplastics, and in particular their high permeability, became relevant to another product in which this feature counts as a virtue. In the words of the interviewees the property of 'low barrier' changes to 'high permeability' and high permeability is treated as a positive value for clamshell packaging. In this case, the quality of permeability is re-elaborated, in that new associations are formed, generating positive as well as negative relations and new material possibilities, such as extending shelf life.

In addition, other features of Ingeo, such as 'stiffness' which were treated as either negative or insignificant qualities for the bottles, were valued positively in the 'clamshell applications.' The 'stiffness' of Ingeo in this particular product was valued as it helped make the end-product more lightweight and meant that less material would be used. Verbruggen explains:

Also because PLA is stiffer than PET, you could actually down gauge so make the walls thinner of these food containers […] on top of that of course, it has the environmental benefits over the traditional plastics like PET.

These two cases, bottles and clamshell packaging, show that the competition is not around the material but the material-product unit. The competition is not between Ingeo and PET, as single, stand-alone materials, but is always formulated in terms of 'a material in a product', i.e., a material-product combination, where the specific qualities are elaborated and potentially extended. As Hawkins (2013a) points out, water bottles became mobile when made of PET.

However, my analysis also shows that the process of elaborating qualities is one in which features are made visible and acknowledged by the relevant users of bioplastics. As Verbruggen explains, different qualities are highlighted for certain products. In short, the qualification of the material is charged with the different interests of stakeholders in the production chain:

If you make PLA for example in shrink film, or PLA for other film applications, the gloss and the brightness of colours if you print on that film in PLA is very very good. So, for that particular application of course, you got to talk a lot about these particular attributes. Now, if you have a very different application, like for example for a compostable item, probably it is not that important that you have great printing qualities, great gloss, so therefore you are not going to emphasize that particular part. So, from a marketing point of view, what you have to get good at, what you have to develop is, which attributes are the most important for particular markets. And then of course *make sure that you target these attributes to the right audience and to the right consumers and customers.*

This suggests that, in addition to qualifying materials always in relation to products, materials producers manipulate the position of materials by making certain qualities upfront for certain audiences and silencing others that might obstruct or contrast with the symbolic and material associations of the material. For example, as the quote suggests, consumers and brands do not expect bright colours and good printability from compostable products, and therefore these qualities are not elaborated in these particular cases.

5.2.2 Substituting with Ingeo in the Process of Production

The instances described above, where materials are evaluated in terms of product form, tells only part of the story through which the qualities of materials are fixed and challenged. I expand on these observations in this part of the chapter by exploring the production processes involved in turning materials into products. I show that further qualities of materials are enacted in terms of production processes. It is useful to state from the beginning that bioplastics are produced using the same production machinery with the same production equipment as traditional plastics. Arguably, bioplastics *have to* fit in the already established technical, as well as social organisation of traditional plastic making.

To explain I describe the production process of water bottles. The production of water bottles, made of either plastics or bioplastics, involves a few steps of specialist processing, each involving a different organisation, often located in separate facilities. Firstly, ‘pre-forms’ (see Figure 5.4) are produced by injection moulding. This is a process in which the plastic granules are heated and melted, and the molten plastic is ‘injected’ through a nozzle into a ‘mould’, hence the name injection moulding. Usually these pre-forms are transported to a blow moulding facility. These preforms are then re-heated (by infrared lamps) and 'stretch blow moulded' into a mould, which is shaped in the form of the bottle by using high pressure air and a stretch rod. During this process, the molecules of plastic are rearranged giving it different capacities than those of the original material.[124] The bottles produced after these stages are then filled with liquids, either in hot filling or cold filling settings. In the case of hot filling setting, the process is somewhat more complicated, in that the bottle needs to be reheated and filled with the hot liquid food item for sterile conditions, and then cooled again.

---

[124] Information accessed from the document on NatureWorks website: http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Storage-of-Ingeo-Preforms_pdf.pdf on 25th February 2015.

Figure 5.4 Left: bottle, Right top: preform[125]

An Ingeo bottle is produced through the same processes as a PET bottle. As expected, the qualities of Ingeo are enacted in relation to previous experience of injection moulding and stretch blow moulding of PET. The fact sheets, information booklets and reports on laboratory tests acquired from NatureWorks' website indicate that Ingeo is mostly compared to PET. However, although the comparison of production-related properties is always established with reference to the production methods involved in making a particular product, these reports evaluate materials as such, and as if devoid of the product context.

[125] Image accessed from http://en.wikipedia.org/wiki/Polyethylene_terephthalate on 1st March 2015.

The criteria for comparing the qualities of different materials in production focus on how easy it is to replace an existing material with the new material, without detracting from product performance and attributes. NatureWorks stresses that 'Ingeo biopolymer can be injection molded and blown using typical PET tooling and equipment.'[126] Examining the production sequence of the bottle reveals that new qualities of Ingeo become relevant in each step of the process.

First of all, the potential and conditions for storing Ingeo granules are compared to those required for PET. Ingeo resin silos should be dry, in contrast to an 'open, vented to atmosphere system' used for PET resin storage.[127] Specific aluminium or stainless steel silos can be used for Ingeo.[128]

Both Ingeo PLA and PET need to be dried before the injection moulding of the preforms. PET has initial moisture of 0.1% and needs to be dried for approximately 6 hours at 160°C to 175°C so as to achieve the maximum acceptable residual moisture content of 50 ppm. PLA has an initial moisture of up to 0.25%, and to achieve the desired residual moisture of below 0.01%

---

[126] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Preform-Design-for-Bottles_pdf.pdf on 25th February 2015.

[127] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Preform-Design-for-Bottles_pdf.pdf on 25th February 2015.

[128] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Preform-Design-for-Bottles_pdf.pdf on 25th February 2015.

requires drying for 4 to 8 hours at 60°C to 100°C.[129] Although technical data for producers contains this information, this quality is not visible otherwise.

Making the preforms is the first step in production and I see further properties of Ingeo are elaborated in relation to PET:

> *Depending on the bottle and machine type, usually using a preform initially designed for PET will work. For the most part, with just changes in some processing parameters like temperature and blow timing, a high quality Ingeo bottle can be made from a preform designed for PET. However, there is an opportunity for improved injection molding and bottle performance with optimized preform mold designs for Ingeo biopolymer.*[130]

As this quotation shows, production equipment is sometimes modified to suit the new material. Moreover, as I observe, the adjustments that the production necessitates are often presented or 'sold' in terms that echo the environmental qualities of bioplastics. For example, the lower operating temperatures are promoted as opportunities for energy savings.

After the preforms are injection moulded they are transported to a blow moulder. The transportation conditions might affect the processing of preforms in the blow moulding

---

[129] Information accessed from http://www.motan-colortronic.com/ca/solutions/injection-moulding/preforms pet-bottles.html on 25th February 2015.
[130] Quotation from the document on http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Preform-Design-for-Bottles_pdf.pdf on 25th February 2015.

machines and further processes. So, NatureWorks has done tests that simulate extreme conditions that the bottle might encounter during transport, where Ingeo is compared to PET:

> *Load tests on preforms showed deformation occurring. After 48 hours, the PLA and the PET performs were heat stable at both 50°C and 55°C. However, the PET preforms were also stable at 60, 65, and 70°C. The PET preforms began to fail at about 75°C. […] The PLA preforms began to significantly fail at about 60°C.*[131]

At the blow moulder, pre-forms are reheated. Blow moulding of preforms is the step where the pre-shaped tubes are stretch blow moulded into bottle forms. Ingeo can be run on both single stage and two stage conventional blow moulding equipment. Re-heating of the preforms 'is critical in getting a container with good clarity and material distribution.'[132] I see further properties coming in relation to Ingeo so as to make it similar to PET in product form in terms of appearance, feel and performance, which apparently depend on the processing of the material:

> *Typical melt processing temperatures for Ingeo biopolymer range from 200-230°C versus 270-290°C for PET. The glass transition temperature of Ingeo biopolymer is also about 15°C lower than typical bottle grade PET. This lower*

---

[131] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_PreformThermalStability_pdf.pdf on 25th February 2015.

[132] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Storage-of-Ingeo-Preforms_pdf.pdf on 25th February 2015.

glass transition temperature means that an Ingeo preform requires a lower temperature for blowing than PET.[133]

In the blow moulding process itself 'the melt processing temperature' is relevant. Moreover, Ingeo biopolymer has a lower extensional viscosity than PET, which is a quality that becomes relevant for 'stretching' in the blow moulding process. Ingeo is defined as being easier to stretch than PET. The property of extensional viscosity is translated in different ways. Since Ingeo stretches more easily due to its lower extensional viscosity the preform should be designed so that it enables equal distribution and prevents accumulation in the base of the bottle, which might subsequently become problematic for the hot filling process, in which the bottle needs to be re-heated.

Exploring the substitution of Ingeo in production reveals that the material is made in and through the existing production organisation, and that specific qualities are defined and valued accordingly. The qualities of stretch ratio and various nuanced heat characteristics become relevant and valued in comparison to PET and existing production arrangements. In looking closer into the production of water bottles from Ingeo, I see that more specific qualities of Ingeo are enacted. I argued that these properties are articulated in the production processes involved in transforming the material into products, and in substituting bioplastic materials for established alternatives.

---

[133] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Storage-of-Ingeo-Preforms_pdf.pdf on 25th Feb 2015.

5.2.3 Further-Production Processes

In this part of the chapter I focus on the further-production processes (e.g. filling bottles) and again show what these mean for judgements of valued qualities.

The definition of Ingeo, grade 7032D, refers to its capacity in terms of 'filling' processes with 'heat setting.' Hot filling, for bottles is used to provide sterile conditions for the packaged beverages, or is a requirement for packing particular products such as sport drinks, ketchup and jams that are 'hot' while being packed. The infrastructure and the technical specifications, such as the temperature of the hot filling processes, are usually already defined or standardised. Ingeo bottles have to fit in this system if they are to have value in this sector, and their qualities are constituted accordingly.

In the hot filling processes, the 'heat resistance' of Ingeo becomes a relevant feature. This actually stands for the 'glass transition temperature', which defines the threshold temperature at which plastic starts to crystallise and so changes its properties and deforms. This feature is not important for bottles designed to contain orange juice or water since these are 'cold' filled. In other cases, heat resistance is again qualified in comparison to PET and the conventions of the hot filling system that have been formed around PET:

> *Since Ingeo biopolymer has a lower glass transition temperature as compared to PET, not all Ingeo bottles that are heat set may be suitable to*

> *package all products requiring hot fill, due to excessive temperature filling requirements.* [134]

The average temperature for hot filling operations is between 85-90°C (however this temperature depends on the application and might change slightly) and unless the bottle is specifically designed for heat setting at this temperature, the bottle becomes soft, cannot maintain its shape and shrinks.[135] Also the mouth and the base of the bottle are more sensitive to heat as these areas have not been stretched in the blow moulding process.[136] Some of the material properties relate to the shape of the products:

> *The bottles used for hot fill applications usually have a high push-up on the base and ribbing for stabilization. Hot fill bottles are typically higher in weight to help improve heat resistance.*[137]

As the material-product combinations of bioplastics are quite varied, the further-processes that the material-product must go through are also varied. My data provide various examples of packaging from hot doughnuts to coffee pods, which have to withstand the pressure of the

---

[134] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Heat-Setting-Ingeo-Bottles_pdf.pdf on 25th Feb 2015.

[135] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Heat-Setting-Ingeo-Bottles_pdf.pdf on 25th Feb 2015.

[136] The mouth and the bottom of the bottle, because they are thicker, hold up to a certain level of thermal deformation. Stability of the amorphous neck and base areas will also depend upon preform design, bottle design, and material distribution. Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Heat-Setting-Ingeo-Bottles_pdf.pdf on 25th Feb 2015.

[137] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Heat-Setting-Ingeo-Bottles_pdf.pdf on 25th Feb 2015.

instant coffee machines. To conclude, in this section, I explored the case of Ingeo in water bottles, and demonstrated the processes through which qualities of materials are made in relation to each other and to products and their production route, and in terms of the potential for seamless substitution.

5.3 Production of Materials: Blends, Specialisation and Compromise

In this section, I reflect on the analysis so far and expand on it by adding broader insights about the making of materials. First, I complicate the product and the production processes. The water bottle was a simple example that I employed to make clear the ways in which materials are oriented to products particularly with respect to substitution. I now go on to discuss two further processes – specialisation and compromise – often involved in the making of materials and the elaboration of qualities in specific material-product arrangements.

Although water bottles are made of only one type of material, in most cases, products are complexes of parts, each made of a different material. Actually, even the water bottle has more than one part: the body of the bottle, the lid, the wrap with printing on it, and the glue attaching this wrap to the body. In some cases, each of these parts is made of a different type of plastic, and sometimes the wrap is made of paper. In other cases, the body of the bottle is itself composed of different layers of materials, each enhancing a certain property such as barrier, adhesion, strength, and visual properties.[138] Andy Sweetman, from Innovia, explains that many products are actually more complex than they appear to be:

> *One of the things that people don't realize is that a lot of the packs, which are on the shelves in the supermarkets, are not just one film; they are a laminate of different layers.*

Sweetman explains that materials are blended to achieve certain product and production requirements. I will elaborate on this point with the example of the coffee pack (Figure 5.5). For a coffee pack for ground coffee, different materials are combined to meet specific product-related requirements, for example: high barrier to keep the coffee fresh; product conventions, such as packaging with printed information on it; and production route – after being filled, the pack has to be sealed on a particular type of machine. As such, as Sweetman explains, a coffee pack consists of layers of different materials:

> *Conventionally for a coffee pack, it is a polyester film, then aluminium foil, and then polyethylene. So, three different materials to marry the different properties. The polyester gives the print-work, the aluminium gives the barrier, and the polyethylene gives the sealability. In this case we have replaced the polyester with the clear NatureFlex[139], the aluminium foil was*

[138] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_CoInjection_MultilayerTechnology_PLABottles_pdf.pdf on 25th Feb 2015.

[139] NatureFlex is the trademarked bioplastic material of Innovia.

replaced by metalized NatureFlex, and the polyethylene was replaced by Mater-Bi[140].

This quote clearly demonstrates that each material plays a different role, and that materials are blended to meet specific requirements for the product, the production process and further processes, e.g. filling.

Figure 5.5 Coffee packaging[141]

[140] Mater-Bi is the trademarked bioplastics of Novamont.

[141] Image scanned from the leaflets provided by Andy Sweetman, the Global Marketing Manager at Innovia.

Despite these features of context specificity, materials are repeatedly discussed as if they have absolute and intrinsic qualities. For example, some materials are said to have 'good print qualities.' The qualification of these materials is obtained through 'qualification trials' to use Callon et al.'s (2002) terminology. These 'trials' and the challenges involved reflect the existing social and technical structure of the sector: for instance, there is a market for packed goods, a tradition of printing packages with information, and a production system composed of different stages and companies. In the case described, one produces the materials, the other does the print-work and produces the packs, and another fills them with coffee and vacuum-seals the packs. The qualities of NatureFlex, the bioplastic film material of Innovia, are elaborated during *all* of these processes.

This is not to deny that materials 'have a say' in what they become, using Bennett's (2010:viii) terms: materials have a 'capacity' which enables them 'not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities, or tendencies of their own.' Mark Verbruggen, the CEO of NatureWorks, says:

> *Some people believe that a product like PLA is somehow magical, it can be used for anything, but of course there are limits. And these are chemistry limits.*

He and other representatives of materials producers acknowledge that materials have tendencies of their own. What I suggest is a bit more nuanced than this. I draw attention to the values given to these properties and underline the point that what values are attended to differs and has a quite specific, often product oriented history. I keep observations about the intrinsic tendencies and capacities of molecules in mind, but expand on this by recalling 'the informed materials' idea of Bensaude-Vincent and Stengers (1996). On the one hand, the valuable qualities that a material should possess, if it is to be used in making a particular product, are defined by established conventions of marketing and production. On the other hand, materials are constantly modified to achieve these criteria.

For example, materials producers use a lot of 'resins' to change or to enhance certain properties of materials. Resins are ingredients that are added to the molten granules at the point of production (and usually designated 'resin producers' formulate and produce these resins). Sweetman, has used the analogy of 'baking a cake' to explain to me the complex nature of the production of bioplastics:

> *We are taking a range of raw materials, and then going through a mixture of chemical and mechanical processes to produce a product. So if we are baking a cake, it is like getting all the ingredients and then we process them, cook them, and we actually manufacture the cake. So it is the same approach in that sense.*

This quotation explains that although there are limits to the capacities of molecular compositions, there are also means with which these can be modified and made more and more *informed*. I will take this analysis of modification and the concept of 'informed materials' of Bensaude-Vincent and Stengers (1996), and argue that bioplastic materials are *specialised* in their making. This concept suggests that materials become more and more customised with respect to end-products and their production. I refer to Paul Mines' explanation that portrays the extent of the specialisation of materials:

> *If you went to Dow, DuPont or BAFS websites, you would see there are thousands and thousands of different plastic types, for very different, you*

know, there is a plastics for Mercedes rear bumpers, for BMW rear bumpers, all with different characteristics […] there are plastics for every possible application, with different properties. But with bioplastics, with each application we have to start again, because we have a range of 20 products not a product range of 2000.

This quotation shows that the plastics industry is extremely specialised, insofar as each car brand has its own bumper material. And bioplastics, which now include a growing range of different types and grades, are following the same route.

I want to draw on Barry's (2005) account of pharmaceutical materials here. According to Barry (2005) who builds on Bensaude-Vincent and Stengers' (1996) concepts, a molecule is a 'historic route' that is fixed temporally. This helps me to see the specialisation of materials as a temporally specific phenomena and I want to note that interpretations of the qualities and hence of materials themselves are constantly changing. This means that the qualities elaborated at one time frame are likely to change as new properties gain value.

Next, I direct my attention to how these forms of specialisation take hold. I suggest that the tension between the 'capacities' of materials, and the extent to which materials can be modified, is a challenge to production in that the extent of possible modification cannot be known before it is tried. This arguably gives an 'experimental' character to the making of materials: it is not always the outcome of a planned corporate research and development process. For example, in the 'technical' data sheets of various grades of Ingeo an awkward expression catches the eye:

Since there are many factors to consider with preform and bottle design, development, and manufacturing, an experimental approach may be needed.[142] *[Underlined my emphasis]*

The explanations of the material processors underline this experimental, trial and error approach. Sweetman explains:

Very often, probably too often, we might try a standard film, and it may fail technically, because it isn't quite strong enough or it hasn't sealed quite enough, you can't, you don't always know enough, about whether it will work. So sometimes you will have to try it, and you just have to accept a degree of failures, maybe one in three, of our trials will fail technically.

He continues his explanation of this trial and error process, which deserves quotation in full:

We have got a customer who makes a particular format of pack, ok? And we tried a 30 micron film, so a film with a particular thickness, and it wouldn't run on the machine. So we tried a much thicker film and it ran beautifully, but because it was so thick, it was really expensive. So they said 'ok, that price is ok, but it doesn't work, that price is too high 'but it works.' So we're now doing test work to maybe develop a particular new thickness film that has the right balancing properties, is cost effective enough but it technically works as well.

[142] Information accessed from http://www.natureworksllc.com/~/media/Technical_Resources/Fact_Sheets/FactSheet_Heat-Setting-Ingeo-Bottles_pdf.pdf on 25th Feb 2015.

This quotation also shows that material customisation involves a compromise among the different actors involved. In the above quote, the compromise was about the economic concerns of the brand and the specific requirements of the food item to be packed. I want to give one more example to develop my point on the making of materials as compromise. Paul Mines, from Biome, says that:

> *[Bioplastics] are not as chemically resistant or heat resistant [as oil based plastics], so probably can adjust and match, but often you have to find exactly <u>the right balance of properties</u> in the bioplastic that allows it to be used in the cycle or application. And that might be temperature stability, might be chemical resistance, it might be colour, it might be light resistance. So you <u>just have to find that point</u> where the properties work for the application, but the material remains to be compostable within 12 weeks, which is the requirement of the standards. [Underlined my emphasis]*

These quotations hint at negotiations among different actors involved in the making of materials. These actors have different interests. For example, brands often value printability, and want their products to perform well, such as designing packaging to keep food fresh. Processors are more concerned about how well the material performs and about its compatibility with their existing equipment. Materials producers highlight different qualities for different audiences. These actors achieve a compromise between these diverse concerns, and materials are qualified in and through these various arrangements.

5.4 Conclusion

This chapter explored the production of bioplastic materials and the processes through which materials are realised in product form. I showed how the product-related qualities of materials are elaborated and realised through different instances of substitution. I also explained the theoretical grounding of this analysis by referring to mainly Hawkins' (2013a) conceptualisation in which materials figure as active agents but in which their qualities are enacted in different arrangements involving both human and non-human actors implicated in their production.

My analysis of the empirical data, provided by the producers of different types of bioplastics, showed that the qualities of materials and their value are constructed in relation to a-) anticipated forms of use and performance, related to specific end-uses and end-products, b-) qualities of the previous materials that were used to make the same product, c-) social and technical traditions of the production processes associated with these specific product-material combinations, d-) the further production arrangements that the material will encounter in use, and the conditions and qualities associated with these processes.

Analysing the production of bioplastic materials as such prompted me to think about the material product relationship that I have initially conceptualised as one in which materials are made into, or transformed into products. However, I discovered that materials are not simply 'applied' but are customised and modified with reference to specific end-uses. This led to the more subtle conceptualisation of modification, in which I suggest that the making of materials involves an ongoing process of specialisation organised around the particularity of anticipated product use, performance, and production. This specialisation was, in turn, an outcome of a process of compromise between the human and non-human actors involved in the making of the materials and products. Hence, the material and the product into which it is turned cannot be thought of separately. Thinking of materials as material-product combinations is perhaps a more useful strategy than that of conceptualising ‘materials’ in the abstract and aside from these relations.

CHAPTER 6

CONSTRUCTING BIOPLASTIC-NESS: MAKING BIOPLASTICS VISIBLE IN PRODUCTS

> *I remember going to the first Bioplastics Conferences, and it was kind of like, a guy would stand up at a conference with a handful of granules and say 'I have got this new bioplastic and it is called blah blah, and there it is!' […] These first guys, they had just developed a technology without really understanding the market.*

Andy Sweetman, Global Marketing Manager, Innovia,
and former chair of the European Bioplastics Association
Quotation from my interview on 26th June 2014.

This chapter comprises the third and the final part of my empirical analysis. To briefly review the argument so far, I began by looking at how the category of bioplastics was made by relevant industries and social groups (Chapter 4), where the focus was on how 'the materials' – bioplastics – were defined, categorised and situated. I explained that processes of definition were charged with varying economic, political, organisational and environmental interests. Then (Chapter 5), I focused on the constructed category of bioplastics and examined the production of different bioplastic materials and products. I initially intended to consider the making of bioplastic materials, however it became clear that the qualities of bioplastics were always elaborated in relation to specific products – i.e. in terms of anticipated performance, the qualities of the materials of which the product was previously made, and the social and technical organisation of the production process. As the previous chapter showed, materials and products cannot be thought of separately.

The current chapter, while maintaining a focus on the making of materials, is more specifically about the characteristics of bioplastic products. It feels necessary from the outset to observe that the range of products made from bioplastic material is somewhat arbitrary: there is no ready-made rationale as to why bottles, tableware or bags should be made of bioplastic. In other words the products that are made of bioplastic are not strictly defined by the properties of the material (as indicated above, these are often customised, and modified). This arbitrariness is also recognised by bioplastic materials producers. Paul Mines, the CEO of Biome, mentions that they could 'have made very good shampoo bottles that look and function just like' the current shampoo bottles, which are currently made of polypropylene or high density polyethylene. Mines states:

> *There is not a logical link between where is the technology capable and where is the most need, or where the most volume would make the difference for bioplastics.*

Mines' comment suggests that the current range of bioplastic products is not logically determined by the technical qualities of material(s), which are in any case elaborated in and through different production arrangements and specifications.

This suggests that the future and direction of bioplastic depends to a large degree on the types of products involved. The reasons and rationales for these products differ. In some cases the ‘bio’ quality resonates with the way in which products are positioned in the market: in such cases it is important to make this quality visible. In other cases, the bioplastic route is taken for reasons that are unrelated to product marketing, but which perhaps relate more to ‘technical’ qualities invisible to the end-consumer.

The relation between material and product, in other words, is ambivalent. In general, the qualities of ‘the material’ are defined and formed by their actual or future application in relation to specific products. At the same time, certain product situations call for overtly articulating ‘the qualities’ of the material itself (as if these were independent of the product). This points to a particular turn in the relationship between materials and products insofar as the making of materials is shaped and influenced by the imperative of making ‘material qualities’ (e.g. being biobased or biodegradable) visible as a feature of the product.

In this chapter I explore issues of material visibility, and consider the ways in which materials are made visible in products. My analysis draws on interviews with the ‘makers of the products’ – which I refer to as brands – and the ‘materials producers’ (specified in Chapter 3). I focus on cases in which both are concerned to qualify bioplastics (in relation to certain products) such that they circulate in markets in a distinctive way, and in so doing effectively define an identity for bioplastics. The qualities these actors make visible are not the same as those which are developed and elaborated in the physical production. For example, the compostability of the coffee pod made of Biome bioplastics is made visible by attaching a label which says ‘compostable’. Although the coffee pod producers have developed other specific qualities, for instance, of heat resistance and precision with injection moulding, these are not the features that are 'advertised'.[143] Moreover, qualities that are made visible vary from one product to another: some emphasise compostability, biodegradability or being biobased. Additionally, brands deploy these qualities to invoke a variety of environmental, ethical, and economic issues, such as waste, water contamination, deteriorating sources, and the like.

This is not to suggest that these features of bioplastics were somehow invisible at the start. On the contrary, producers and those who convert materials to products are well aware that they are dealing with bioplastics, and that they are doing so in the context of changing markets especially for 'green' products. However, as my analysis shows, from a production perspective, other features such as permeability or melt temperature proved critical in defining the material-product relation.

In reviewing these overlapping relations I want to draw on Marres' (2014:260) analogy of 'generative story-telling', which she uses to elaborate on the 'capacity' of objects to invoke a range of issues. Marres explains a type of children's generative story-telling game, called the 'teapot', in which the narrator says 'teapot' to signal to the audience that this part should be filled by them. As the name suggests, a story is *generated* while being told. Like the 'teapot' game, people engaged in the making of bioplastics fill the 'teapot-blanks' by making certain things visible in certain product arrangements, and in doing so they tell a story of bioplastics. It is through such story telling(s) that bioplastics are continuously made: this is also how they evolve, are generated and gain an identity.

---

[143] Derived from my interview with Paul Mines, the CEO of Biome Bioplastics, on 8th Aug 2014.

In focusing on these processes this chapter details another type of relationship between the material and the product and by doing so it bridges between the previous chapters by linking the different worlds of category making and physical production with brands and brand identities. I argue, then, that materials are (re)generated in and through the particular products into which they are made and that in some cases material visibility represents a route through which the category of bioplastics is made and reproduced. This positioning is in turn important for the development and future of bioplastic material-product relations.

I start by exploring the different forms of visibility implicated in particular product-material relations (Section 6.1). Here, visibility is not simply a matter of making certain qualities recognisable, it also represents a process through which bioplastic-ness is articulated via particular material-product relationships, as these are constituted by the materials producers and brands. In practice it is not easy to separate out these forms of visibility in that they are combined in the design and positioning of products which 'address' consumers in complex market environments.

The cases introduced in the following sections each highlight a different aspect of these relations, and each illustrate a different mode of remaking bioplastics. The first case, the 'compostable waste bag' (Section 6.2), demonstrates the ways in which the mobilisation of a quality, compostability – in a particular material-product combination, waste bags, within the political and economic concerns of the municipality of Milan – *redefines* bioplastic in that it forms new social and material relations around the compostable bag. The second case, the 'compostable coffee pod' (Section 6.3), exemplifies *positioning* an already articulated quality – compostability – in an 'issuefied' material-product combination (to use Marres' (2014) term 'issuefication'). In this case, the 'issue' is that of the wastefulness of extensive packaging, an issue in which compostability is located so as to create a marketing advantage. The third case, 'biobased packaging bottle' (Section 6.4) shifts the focus to qualification of the source of the material (biobased). This case demonstrates the multiplicity of issues that a material can invoke, showing how it serves to *reposition* goods continuously, as well as demonstrating how issues are articulated around moral and ethical concerns. The fourth case, the 'conspicuous salad bowl' (Section 6.5), specifically focuses on the manner in which the bio qualities of the material are pointed out, and suggests that this conspicuous form of visibility configures a distinct identity and iconography for biobased-ness, thereby *redefining* the material in a certain way.

However, there is a twist in the story at the end of the chapter (Section 6.6). My empirical data also pointed to cases of carefully constructed invisibility. In these cases some brands intentionally obscure the bioplasticness of the materials they use, in effect *dispositioning* them from a 'bio' identity. The materials involved are configured in other ways, and are deliberately not situated as 'bio' for reasons that are themselves revealing.

In short, this chapter argues that methods of making material properties visible *remakes* materials through modes of *redefining*, *positioning-repositioning*, and *dispositioning*. In the conclusion (Section 6.7), I discus the emerging tensions between visibility and invisibility, and between the product and the material.

6.1 Forms of Visibility and Material-Product Relationships

This section discusses three different forms of visibility that characterise material-product relations. To start from the beginning bioplastic materials have to be made visible, as in recognisable and identifiable, by being pointed out and by being distinguished from other forms of plastic, whether by the materials producers or the brands. Since bioplastics do not have a distinct or singular appearance, like wood or metal, unless identified as bioplastics, they remain unnoticed and invisible. If not overtly named as such, bioplastics are most likely to be mistaken to be traditional plastics, since their visual qualities are almost the same, and deliberately so. This ambition of seamless substitutability might obstruct bioplastics' distinctive positioning in new networks. For example, as one of my respondents explained, composting facilities are sceptical about bioplastic objects since they look as if they are made of traditional plastics, which would contaminate the composting process. In these cases, bioplastics *have* to be pointed out. This form of visibility, that is, *pointing out* (and *identifying* and *making recognised*), is done in different ways. Official labels, certificates, symbols, markers and leaflets are all used, as is the strategy of making sure that the product looks different. When brands want to make the bioplastic quality invisible, they simply fail to mention this feature. It is only by virtue of being pointed out that bioplastic figures in the market.

MacKenzie (2012:53) in his account of the political and economic entanglements around the multiple definitions of carbon emissions touches on a similar challenge: 'Of course it was ambitious to set up a market for something you can't see…' According to MacKenzie, making the invisible-to-the-eye carbon emissions visible meant that carbon is made 'economically visible by giving it a price' (MacKenzie, 2012:54). In his account, 'visibility' meant that the terms with which to define and measure carbon emissions had to be articulated to be able to create a market in which the invisible is exchangeable. Similarly, my empirical data showed that making bioplasticness visible meant that it needs to be 'qualified', to use Callon et al.'s (2002) term. When certain qualities of bioplastics are made visible, bioplastics are *qualified* or offered as the solution: more specifically, the qualities *invoked* and *translated* typically relate to environmental issues. Invoking qualities goes hand in hand with the strategy of making an 'issue' visible, with *raising* or *articulating* an issue.

These forms of visibility (material visibility, invoking qualities, and issue visibility) are varied and complex, and it is hard to separate them out. There are revealing similarities between the case of bioplastics and Marres' account of the different deployments of eco-homes as devices for 'public participation'. She argues that publics are formed by 'articulating an issue' in the media (Marres, 2008). These publics are 'fragile, undetermined, and ephemeral' (Marres, 2008:40), suggesting the dynamic nature of the issues and their audience. This view helps me to understand how different qualities of bioplastics are related to different issues.

I observe that different qualities are invoked to address a range of different environmental issues. As well as presenting a challenge, I realise that the intrinsic tension between invisibility and what to make visible, presents flexibility in bioplastics' articulations, as to what they are.

Marres' more recent studies, which focus on the positioning of specific objects, are closer in their scope to my own work. Marres (2014) elaborates on the range of issues that objects are 'used to conjure up,' stating that objects have a 'capacity' to invoke issues. She terms this as 'issuefication' of objects, which she defines as 'a dynamic in which an object comes to 'resonate' with particular matters of concerns' (Marres, 2014:11).

Although Marres studies objects, my cases are different because of the complexity of the material-product relation. Sometimes the product itself is charged with certain issues and associations, to use Marres' terms. At other times, bioplastics – as a class of materials – bring specific qualities to products and to the terms in which products are judged and reproduced. The qualities that are made visible in product form define what is at stake and serve to position the product and the material in new networks and practices by detaching it from those of its production and involving it with consumer and end use networks. The following cases exemplify different aspects of these relations.

6.2 Defining New Relations for Disposal: Making the Waste Bag Compostable

The case of compostable waste bags made of Novamont's trademarked material – Mater-Bi, within the 'Milano Recycle City' Project – shows how Novamont, the materials producer, focused on organic waste as an economic and environmental concern for the Municipality of Milan and offered compostable bags as part of the solution.

Compostable or biodegradable bags were one of the first commercial examples of bioplastic products circulating in the market with a bio identity. To make a place for these products, and for biodegradability, materials producers built new alliances with local authorities and with processes of waste disposal. The Milan project (started in 2012) is not the first example in this sense; Novamont has been working with several municipalities in Italy since the 1990s.[144] However, I focus on the Milan project as a large scale example which enables me to articulate the different visibilities at play and to illustrate an effective configuration of material-product relationships. This section is mainly informed by my interviews with Francesco Degli Innocenti, the director of the group for Ecology of Products and Environmental Communication at

[144] Also there have been other countries where different municipalities and material production chains collaborated.

Novamont, and by the documents on the Milan project provided by Christian Garaffa, Marketing Manager for Source Separation & Recycling.

Briefly, the Milan project worked as follows: The Municipality of Milan supplies households in Milan with compostable bags, which are made of Mater-Bi, the trademarked material from Novamont. After this initial supply of bags is finished citizens must buy their own compostable bags or reuse the compostable bags of retail chains (which are mostly made of Mater-Bi). Citizens are expected to sort out their organic waste and dispose of them in these compostable waste bags. These bags are collected in a designated waste container supplied to the households, again by the municipality. From this point on the waste collection and street cleaning company, AMSA SpA, takes the separated organic waste and transfers it to Montello, which produces compost and biogas from the organic waste. The Italian Compost and Biogas Association (CIC) and the National Paper and Cardboard Recycling Consortium (COMIECO) are involved as well, helping to monitor the quality of the compost and to advise the related groups. Consumers can distinguish compostable bags from others by the label certifying compostability that is stuck on them. The standards of compostability that are signalled by these labels mean that compostable bags can be *identified* by their various users, and can therefore figure within and constitute the system offered by Novamont.

Novamont is the key player in the enactment of compostability: it has worked to raise organic waste as both a problem and an opportunity for different actors and to bring them together around this topic. Organic waste was an issue rendered problematic for the municipality because it smelled bad.[145] It was also given an economic value by comparing the cost of composting to landfill costs. In this context, Novamont proved that the collection of organic waste would be less costly compared to other methods, and that the waste that is turned into compost and biogas would provide new 'bio' resources for the municipality. Subsequently, Montello, the composting facility, would also have more material to compost, and so more biogas to sell.

Innocenti explains how Novamont raised household organic waste as an environmental issue for the municipality by articulating organic waste as 'the waste number one':

> *Basically the principle was to point out to municipalities and to explain them that organic waste being probably the waste number one in terms of weight, the waste number one in terms of, ehm, the problems that this waste can create, because of smell, because of fermentation and so on, explaining to the municipalities the need to organize the collection of organic waste besides, glass, besides paper…*

Innocenti continues explaining how compostable bags were offered as part of the solution to this new waste problem:

> *So the idea was to convince municipalities and citizens that by using compostable plastic bags it was possible to have the collection of this*

---

[145] As Innocenti, the director of the group for Ecology of Products and Environmental Communication at Novamont, states the household organic waste has also been identified as an environmental issue by the European Commission.

fraction that is usually slimy, smelly or not really nice, to be combined in a bag, that was similar to a plastic bag and on the other hand it was also biodegradable, so giving rise to good compost. And that was the message. The message was really powerful in a way…

This quotation clearly shows how a particular quality of bioplastics was layered with the particular problem of organic waste, and that this effectively mobilised compostability in waste bags.

Arguably in this system, composting facilities were the epicentre, where all the human and non-human actors, municipality, biogas production, compostable waste bags, and organic waste, came together. Innocenti explains that the composting facilities were crucial to the configuration of this whole waste management system:

[It is] important to have a good relationship with the composters. Because at the end of the day they are those who are the final, let's say, step, of our road. So they are those who have to make the decision whether to accept the waste containing compostable plastics. So, if they are, not satisfied, not convinced, if they are not willing to accept the compostable products [meaning the compostable material-product combination], we have a big problem.

He explains that in the beginning Novamont worked in close collaboration with the composters to convince them that compostable bags made of Mater-Bi do not contaminate or obstruct the composting process. He explains further that it is important to maintain relationships with the composting facilities:

So you must really, let's say, get in touch with composters, with the composting associations and so on. Whenever new products; for example, tableware, are introduced on the market, it is important to be sure that the composters are informed, they can run tests if they wish to do so. Otherwise they can just reject them. This is clearly a sensitive point, for the whole chain.

These quotations focus on the municipality and the composting facilities, both of which were clearly crucial to Novamont. However, I want to draw attention to yet another set of relations that revolved around the compostable bag. By introducing biodegradability as a new material category, the municipality of Milan calls upon its citizens and invites them to participate in a form of environmental politics.

To reiterate, this strategy depends on making the biodegradable qualities of the bags highly visible. Innocenti explains:

In the beginning, composters, are really sceptical. They are really afraid to accept materials that look as plastic, because for them plastic is a problem. So the idea to accept products that look like plastic is difficult.

In this case, the fact that bioplastics cannot be readily distinguished from traditional plastics created a problem that the labelling sought to solve. It necessitated that compostable bioplastics be made clearly identifiable for citizens, waste collection and management organisations and the composting facilities. Making certain bags identifiable as compostable waste bags served to separate these products from other types including carrier bags, paper bags, cotton bags and the like. The new quality also called for the re-arrangement of material categories, requiring a clear cut distinction between those that are compostable and those that are not. Innocenti mentions:

> *If you use compostable plastics, this waste will become a waste that is homogeneous in the sense that it is all compostable, because we had the organic waste that is biodegradable and compostable, and we will also have the plastic items, plastic products that are compostable. And they can be recycled together by means of composting.*

This quote refers to a general categorisation of materiality that was shaped by the mobilisation of compostability in waste bags. Framed like this the new compostable bag becomes part of a system rather than a product on its own right; it is not a waste bag anymore, but it is a compostable waste bag, for compostable waste, to go through the composting route – more closely allied with, for instance, vegetable waste than with bags made of some other material.

Furthermore, making compostability the core visible quality of this material system involved creating a whole set of relations and networks of practices produced and reproduced between humans and non-humans, and among non-humans. The new compostable bags necessitated new relations within the municipality of Milan and with citizens of Milan, waste collectors and composters, also requiring new practices of sorting organic waste, putting it into a compostable bag, and handling this material as a single 'compostable' element.

It is important to mention that this widespread use of compostable waste bags was only possible because of an already existing composting infrastructure and a tradition of waste separation. Organic waste problem definitions drew on this infrastructure. In addition, in Italy plastic bags were a product category already associated with environmental harm.

Consequently Italy has been the first country to ban plastic bags in retail chains, in 2013.[146] There was already a legal structure that obliged supermarkets and retail chains to hand out compostable bags or to sell multi-use bags in store[147] and for these reasons citizens were already familiar with the compostable bags.

To sum up, organic waste was positioned as a matter of environmental and economic concern. This enabled the effective promotion of biodegradable bags as part of a wider strategy of municipal composting. Innocenti explains:

> *We get a successful market, so we get successful applications whenever there is a strict relationship in a way between plastic and food. Plastic waste and food waste. So this is the two keywords in our business.*

Novamont, the materials producer, actively worked on raising this issue of waste and translating its product/material as part of a solution in which new and old practices and infrastructures were woven together. I argue that making certain qualities visible in particular material-product settings effectively produces and reproduces new relations among humans and non-humans – between bioplastic producers, composters and municipalities, at the same time reproducing new categories of materiality. As such, bioplastics are re-made by means of *re-defining* their relation to other material entities, in this case including food, other bags, and other forms of waste.

---

[146] Information accessed from plasticnews.com on 17th Sept 2015.

[147] Information derived from the document provided by Novamont titled as *Food Waste Recycling in a Densely Populated European City: The Case Study of Milan*.

6.3 Positioning Disposability: Making the Compostable Coffee Pod

The previous case focused on a situation in which biodegradable bags were translated as a solution to organic waste as an issue within regional politics. The case of the compostable coffee pod illustrates the ways in which qualities of compostability are invoked as part of a green and environmentally friendly marketing strategy. I consider the compostable coffee pods made of Biome's bioplastics to show how compostability – an already articulated, standardised and certified quality – is translated into coffee pod form.

Coffee pods are the little capsules that are fed into an instant coffee machine (see Figure 6.1). Although an ordinary consumer would not realise this, there are different parts of the pod: the pod container, the filter, the ring around the filter, and the sealing film. In the case of the compostable coffee pod, each of these parts is made of different types of compostable bioplastic, processed by different companies using different machinery. The packaging in which these pods are wrapped is also made of compostable materials, cardboard and bioplastics and is more visible to the consumer.

My discussion of this case is informed by my interviews mainly with Paul Mines, the CEO of Biome, and by the information he provided about their customer (the company preferred that the customer is not identified here), as well as some complementary information provided by Andy Sweetman, the Global Marketing Manager of Innovia, which is a major materials producer that supplies only to the packaging industry.

Figure 6.1 A coffee pod[148]

This customer of Biome wanted to make their pods compostable so as to *position* their products as 'premium' and as being environmentally benign, in an imagined niche market in which consumers are thought to be willing to pay extra for these features. Coffee and especially instant coffee is a fast growing market, both in America and in Europe. According to the report of the International Coffee Organisation, in 2004-5, coffee was the world's second most widely traded commodity after oil (Murray and Raynolds, 2007:3). Some parts of the coffee market already have Fair Trade and green aspects to them, and there is in addition a niche market for speciality coffee associated with a higher price, superior taste, high quality beans, and different flavours and roasting processes. Within this speciality market there has

[148] Image accessed from http://www.eppm.com/downloads/368/download/Biome-2.jpg?cb=a457549a41a 2692b1b6ea3e6dd12ed73 on 15th Sept 2015.

been a further differentiation of 'Organic' and 'Fair Trade' coffee, which has been growing at a yearly rate of 69 percent since 2000 (Grodnik and Conroy, 2007:84). Grodnik and Conroy (2007:85) state that 'the specialty coffee industry prides itself on an industry wide commitment to environmental protection and social justice.' This commitment regarding coffee production feeds through to the packaging, meaning that 'green' qualities are valued across different dimensions of the product as a whole. As my respondents state, the Fair Trade coffee sector has become a major consumer of bioplastic packaging. Sweetman explains that coffee (and tea) sectors include niche markets that are already organised around issues of organic production and Fair Trade:

> *There is such a, such a strong link between, teas and coffees and the growers. So you have a lot of organic or natural Fair Trade within tea and coffee segments. And consumers often as well are quite interested in where the coffee came from or where the tea came from, different flavours, different blends, and so on. So it is a segment, they are a segment which is already quite premium, and also where there is already quite a natural aspect to the whole question.*

Because there is a sector of the market interested in the environmental aspects of the coffee supply chain, there is also scope for promoting an environmental message regarding the packaging. Mines explains that NGOs involved with the coffee sector have already raised concerns about the 'over-packaging' of single serve coffee:

> *The problem with single serve coffee is that it uses a lot of packaging […] you know how as set of packaging for each cup full of coffee you have. So the industry is very aware of that. […] Well, you know the coffee makers*

want you to feel that your coffee comes from a Fair Trade source, is sourced ethically, and the farmers are fairly compensated and that you can feel good about your cup of coffee, yeah? And so, one of the problems they have is some environmental clash, around the amount of packing of single serve. […] Some of the consumer organisations or the environmental organisations were starting to say 'this is going in the wrong direction', because where you used to buy a bag of coffee and make a cup yourself, now with these pods, you have to have packaging for every single cup you make, because each pod makes one cup, yeah. So this is going in the wrong direction, so they [coffee brands] were under some pressure to do this.

One consequence is an interest in reducing packaging waste. This is different to the issue addressed by Novamont, which focused on methods of handling compostable food waste. In this example, it is the product (the coffee pod) that is problematized or in Marres' terms (2014) 'issuefied' in ways that resonates with ethical concerns of certain coffee consumers.

Until recently there were only a few compostable packs used for ground coffee or in the single serve coffee market. The customer of Biome, which is a small scale family business specialising in fair trade and organic coffee, was the first to make the single serve pods wholly compostable. This development built on what was an already growing industry in bioplastics related to food packaging. Mines explains that the problem of 'over' packaging single serve coffee was taken up by coffee brands, such as their specific customer. In this context, compostability was invoked as a solution to the problem. Mines states:

> *So we have been for four or five years with several customers in the USA, to come up with a product that enables the pod to be put in the food waste [meaning compostable]*

Mines explains the mobilisation of compostability in relation to coffee pods as follows:

> *I think they wanted to be able to say, because coffee grounds themselves, you know, the residual coffee, is biodegradable, compostable, so they wanted it to be able to have a product that was, that you can throw the whole item in the trash, coffee and plastic. […] Each 20 pods are in a bioplastic bag and that bioplastic bag sits within a recycled cardboard box, so the whole product, from outer box to bag, to pods, and the coffee is all compostable.*

The concept of a compostable pod helps position the product in an imagined market: specifically, it takes environmental concerns associated with the production and supply of the coffee through to the packaging. In this way both the product and the material are deliberately *positioned.*

The above quote points to another important aspect of the material-product relationship. In terms of their compostability, the coffee pod and the coffee grounds become one single unit. Previously, consumers had to take out the grounds and separate them from the non-compostable pod. With the compostable coffee pod, the coffee and the pod merge. This move changes the status of the packaging. Strasser (1999) in her study of social transformation of 'trashing', states that packaging was bought to be thrown away: it is made to be wasted. Compostability *re-positions* the status of the packaging such that it is arguably 'bought to be composted.'

Furthermore, the compostable coffee pod illustrates the point that products are composites, meaning that they consist of multiple parts made of different materials. This creates challenges in articulation. For the total product to qualify as being compostable all the parts of the unit, the tiny parts of the pod, the different parts of the overall packaging, all have to comply with the standard specification of compostability.

In the case considered here the material and the product become united around the visible quality of compostability. This case also shows how brands develop an 'issuefied' product, invoking specific qualities so as to create favourable market positions: such efforts *re-position* the status of the product and the materials of which it is made thus *remaking* bioplastics by associating the category with new ambitions and concerns.

6.4 Making the Source Visible: The Case of the Biobased Bottle

The previous examples show how bioplastic materials were valued in relation to questions of waste and disposal. Ecover's biobased bottle brings other qualities into view. In this case the focus is on the source of the material and its biobased origins, and with considerations that reflect a range of moral and ethical concerns. Initially referred to as 'Plantastic', then as 'Plantplastic', Ecover uses a composite material made of 75 percent biobased and 25 percent recycled plastics. In describing this material-product relation I show how Ecover *re-positions* biobased-ness in terms of the company's ethical values and how it uses this to establish a distinctive market position. This strategy is of consequence for the detailed composition of the material, also informing the product (a bottle) insofar these new qualities and values situate the product in new networks as well as within new discourses and categories.

The account offered here is informed by my interview with Tom Domen, the long term innovation manager of Ecover, as well as by Ecover's website and online documents. Some complementary examples are drawn from my interviews with various materials producers.

Companies constantly define and redefine the meaning of social responsibility, and corporate norms and values are often in flux (Murray and Raynolds, 2007). However they are defined, these 'values' inform the qualification of materials and products. Ecover, a company producing cleaning chemicals, was founded on certain principles, one of which was to avoid harm to the water ecosystem. In practice this involves producing biobased chemicals and as Domen explains this commitment spilled over into an interest in the biobased quality of the bottles in which cleaning products were sold:

> *We, as a company already have a long track record in biobased chemistry in biobased ingredients, for our product formulation. And so we are also looking into improving the sourcing of materials we use for packaging, which were at the time [2000s] still petrol based, so we wanted to have biobased alternatives.*

This quotation also implies that Ecover's consumer base was already concerned about ecological impact. Ecover has actively encouraged this interest, for instance by providing consumers with an opportunity to re-fill existing bottles so as to limit the number of new (environmentally problematic) plastic containers in circulation. This is in keeping with a strategy that favours environmental consistency across the company. As Domen says:

We have an image to keep, as a kind of pioneer, we can only keep that image through doing these kind of things [talking about launching a biobased packaging bottle]. The pioneering image comes through different actions that we take.

In keeping with this approach, 'Plantastic' bottles were produced in 2010 and were made from bioPE produced by Braskem. After a trademark battle with Coca-Cola, Ecover settled on the name 'Plantplastic Bottle.' When it was launched Ecover ran a publicity campaign to advertise their new container. Currently, the use of 'Plantplastic' is indicated by a special symbol (see Figure 6.2) and explained on the Ecover website along with all the other symbols on the products.

Figure 6.2 Plantplastic symbol on the right bottom of the bottle (next to the official symbol of 'Cruelty-free' – leaping bunny).[149]

[149] Image derived from http://pt.ecover.com/image/hero/864x740!/205en.png on 1st Nov 2015.

As Domen explains the biobased bottle was repeatedly re-articulated to create or maintain a distinctive market position and to provide new and hopefully appealing qualities to Ecover consumers. In all cases the focus is on the sourcing of materials. However, the details have varied. In the first instance the Plantplastic Bottle was made of a mixture of different materials, 75 percent bioPE, and 25 percent of recycled plastic. Ecover advertised its use of recycled plastic with the phrase 'Message in our Bottle.' With this move they sought to address concerns about plastic waste. Taking an active stance, Ecover turned plastic waste into a useful bottle, using a single product to link discourses of recycling and waste (25 percent recycled) with other interests in sourcing bio-based materials.

Tom Domen explains how the company connected these ideas:

> *Even our plant based plastic is no end solution to the big issue plastic is causing, namely, ending up as litter and then ending up in our oceans and disturbing all the ecosystem there, and in the end returning back to our plate. So, we wanted to do something on that issue.*

Ecover introduces the concept of 'Ocean Plastic', situating this as both waste and as 'useful' raw material and publicises this via the media and YouTube videos so as to appeal to consumers' sense of environmental responsibility. Domen explains how Ecover came up with the idea of using ocean plastic as a 'solution' to the much publicised problem of plastic waste in the oceans:

> *So we started looking what we can do in this area [ocean plastic waste]. And we started with two streams; one is [using bioplastics that biodegrade in the marine environment, which was not technically possible yet] and then,*

the second thing was, at least can we do something about the waste that is ending up in the ocean. So then the idea came that we, try to make the awareness that is the big problem, and so clean up some of the mess you have created.

Domen's explanation shows that there are different ways in which companies can address an issue and that this can lead them to articulate different qualities of their own products. The following quote clearly explains Ecover's motive in positioning their brand in relation to various environmental issues and articulating and modifying their bottle as a response to these problems:

We are into this ocean plastic, so we are using collected ocean plastic and turning that into a bottle which we notice is a story a lot more engaging than biobased plastic.

Although initially concerned with sourcing (whether from biobased or recycled plastic) Ecover has begun to consider biodegradable options. As the previous two examples show, compostable packaging is a growing niche within the packaging sector. For Ecover to take this route, the company would have to ensure that a compostable package was compatible with the chemical properties of its products. Some of Ecover's products, such as detergents, were changed such that they could be combined with new biodegradable forms of packaging. Domen explained how Ecover made powder capsules rather than liquid detergents, enabling them to make the packaging biodegradable:

So one thing that we could change was to make all our products not in a liquid format but in a solid format, which makes it technically already easier

> *to use biodegradables, so we have designed a whole line of biodegradable products, a whole line of solid single dosed tablets that are packed in several options of biodegradable materials like paper foam, fibre foam material […] you can make laundry product in a powder, you have mono-dose, which are very popular nowadays, liquids mono-dose, which are packed in a dissolvable plastic which is not biodegradable. So we then look for alternatives. You want to work with biobased biodegradable materials, you cannot work yet with liquid formats, so we are looking into solid, solid mono dosed tablets that are packed into biodegradable pearls, and biodegradable trays, that can be either home compostable or industrial compostable.*

Domen's explanations show that aspects of packaging can work back up the supply chain and influence the design of the company's main product, the cleaning chemicals themselves. These examples, including the emphasis on corporate consistency, provide insight into the processes through which values and materials are reproduced.

In concluding this part I want to draw attention to the impact of packaging on the product that is contained within. The bottle's status in relation to its contents has changed as a result of the diffusion of environmental concern, and the pursuit of consistency in this respect. The bottle has become a visible and important part of the product. Frank Cochoy (2005) in his account of the evolution of grocery trade, mentions that packaging demonstrates the values of the product inside. However, Ecover's deployment of bioplastics, associated with the issuefication of packaging as an environmental hazard, means that the packaging has come to be seen as a feature or property of the product it contains. The fact that it is stored and sold in a biobased Ecover bottle is listed as one of the qualities of the product and through moves of this kind both the product and the material are *repositioned* in various ways.

6.5 Being Biobased: The Case of the Conspicuous Salad Bowl

My last example illustrates methods of visibly labelling the qualities of a material-product so as to give it a distinct identity. In the examples referred to above biodegradable or biobased qualities were pointed out in different ways: Sometimes this involved reproducing the logo of a certifying organisation (signifying compostability – as in Milan compostable waste bags); sometimes the company produced a symbol of its own to indicate biobased-ness, as was the case with the Ecover bottle. In the case to which I now turn, the Zuperzozial tableware range is designed to display the natural and biobased aspects of bioplasticness. In taking this approach the company starts to establish a visual identity for bioplastics. This is especially interesting in that bioplastics are normally made to be indistinguishable from the materials they replace. In creating a look and feel for 'bioplastics' Zuperzozial products seek to convey the message that they are made of something different. The distinctive look of the material is made to enhance the image of the product.

Zuperzozial is a sub-brand formed to promote ecological goods within the company Capventure. Zuperzozial tableware products conspicuously present and construct an image of the material of which they are made (see Figure 6.3). The identity of the product is anchored in its 'bio' properties and these are communicated in design and appearance of the product itself. Since the only distinctive feature of a Zuperzozial salad bowl is that it is made of a type of bioplastic, the product needs to somehow make this feature evident to potential consumers.

Figure 6.3 Zuperzozial salad bowl[150]

At first sight, the bowl in Figure 6.3 looks like any other salad bowl, but on closer inspection it looks as if it is made from some kind of coloured chipboard. Tiny particles of bamboo are visible among the pale colours of the plastic. In this case the brand is trying to promote the natural and environmentally friendly identity of bioplastics by making these bamboo particles visible. The iconography of the product expresses its material, associated with wood rather

[150] Image provided by Remco van der Leij, the co-founder and designer of Zuperzozial brand.

than with plastic. This is a positive step in that wood has none of the negative environmental associations of plastic. In making this association the bowl signifies its natural status: it is natural, it is wood-like, but not quite wood. As the designer and partner of the brand, Remco van der Leij states, the product also buckles and changes its shape a bit over time, which adds to the natural image of the product and sets it apart from perfect machined and 'unnatural' plastic products.

Importantly, the message is not conveyed by the object alone. The distinct look of the object is reinforced by a sticker explaining that it is biobased and biodegradable. The sticker provides an account of the distinct look and of how it is to be interpreted.

To the extent that this redefining of both salad bowl and of bioplastics succeeds, this new visual identity (and its associations) becomes normalised. When bowls that look like this are automatically assumed to be biobased, there is no need to make this quality explicit. More broadly, the point is that as with the logos, standards or symbols that are used to make bioplastics visible, their widespread use has the opposite effect. Once accepted as normal these same signs render bioplastic invisible: once there is no need to articulate or explain or discuss what bioplastic means, it becomes a non-topic.

Bioplastics come to be through a constantly shifting landscape of categories, relationships and forms of visibility. These shifts are part of dynamics of an emerging field in which qualities and categories are stabilised for longer or shorter periods of time. Once provisionally established and effectively articulated, these distinct identities begin to blur: bit by bit they start to become invisible as the category itself is 'naturalised'.

6.6 Disposition and Invisibility

So far, I have explored forms of articulation and methods of making visible that characterise the making and remaking of bioplastics. However, as I mentioned in the introduction, there are also cases in which the distinctive qualities of bioplastics are omitted or deliberately made invisible. I encountered two forms of invisibility. One is when bioplasticness is deliberately obscured to dis-position the material (and product) from associations with bioplastics and related infrastructures or markets. The second form of invisibility arises in situations in which bio-qualities are not relevant for the market positioning of companies, or for company values and in which consumers are not expected to share green values, or be willing to pay more for this kind of association.

The first form of intentional dispositioning is motivated by an economic interest in not appearing to be distinctive or special. In such situations brands are aware of the bio-qualities of bioplastics and associated meanings and networks, but deliberately obscure these features. Marc Verbruggen, the CEO of NatureWorks explains that some brands are concerned about the potential economic implications of acknowledging their use of bioplastics:

> *In the world of PLA, in the world of 'Ingeo', NatureWorks is the only supplier of these sorts of products. And what brands are always concerned about, from an economic point of view, is that once they start to advertise they are using PLA, that when their consumers actually see that, that consumers would then demand it, and then of course that NatureWorks will say, now that your consumers demand the use of PLA, now we are going to increase our price. And of course buyers at the big retailers, and the buyers at the*

> *big brands, clearly don't want to be in the position where they have no leverage, where they have no buying power.*

This example reveals some of the risks involved in promoting a strong bio-based identity. First, there are fewer suppliers meaning that companies which highlight such qualities are at risk of locking themselves into a vulnerable position. Second, the ‘image’ of bioplastic is only positive if it resonates with other features of brand or company identity. If there is no such link, the image can be counterproductive. Andy Sweetman, Global Marketing Manager of Innovia explains:

> *Particularly big brand owners, they are nervous about making environmental claims, because they think that the green groups, like Greenpeace, are just going to try to pick holes in their arguments: 'Okay, you say you are green, but you are not really green!' So, some of them are just more quiet about it.*

In these cases making the bioplastic quality invisible is a form of brand strategy and is itself part of brand positioning.

In other cases, the bio-qualities of materials/products are irrelevant and therefore invisible to the brands themselves. Sweetman mentions that ASDA, a major retail chain, which uses Innovia’s NatureFlex for the packaging of their ‘Extra Special’ range of potatoes does not announce the material’s bio-qualities:

> *For this customer, it is all about technical performance. Although they are using our renewable and compostable films, there is no green messaging at all, it is just about shelf life extension. […] Just not in the message at all. It’s all about product protection, that's the key motivator there.*

In this case, ASDA is interested in a technical quality of the material (developed for the purpose), namely its permeability (see Figure 6.4). This allows the products to be kept fresh for longer compared to conventional plastics. Although Innovia was keen to promote the bio-qualities of the material, these were of no concern to the brand.

Figure 6.4 ASDA potato packaging made of NatureFlex material of Innovia[151]

In other cases, concerns which are visible and important in some sectors are of little or no significance in others – meaning that the environmental aspect of bioplastics carries no weight. Paul Mines, the CEO of Biome, explains their unsuccessful attempts to promote

[151] Image scanned from the leaflets provided by Andy Sweetman, the Global Marketing Manager at Innovia.

bioplastics in the packaging of building materials, by invoking the compostable qualities of the material:

> *We have gone and talked to building research, builders cause a lot of the waste, if you look at where the packaging waste is generated, a huge amount of packaging waste comes on building sites because everything you put in, radiators, floorboards, roof tiles, all come to the building site packaged, and the quantities there are big as well, they are vast, nothing compared to your weekly shopping, but there is no real interest in sorting that out.*

Mines claims that although the building sector is interested in some environmental issues, such as energy reduction and energy efficiency (when buildings are in use) these concerns do not extend to matters of construction waste. The potential for mobilising concerns about waste, as in food packaging, is apparently not the same in the construction sector.

Although I have mostly focused on methods of making and positioning bioplastics by making them visible, it has been useful to consider modes and forms of invisibility. The examples cited above hint at ongoing negotiations about the status of bioplastics in relation to different concerns (environmental, economic) and product sectors. They also suggest that there are limits, and that it is not always possible to generate and capitalise on issues to which bioplastics are the answer.

6.7 Conclusion: Tensions between Visibility-Invisibility and Material-Product

This chapter elaborated on the processes involved in making materials visible in product form. It did so by describing the different forms of visibility that are implicated in particular material-product combinations and that are part of constituting material-product relationships. I showed that what is made visible to consumers who confront specific product-material combinations is just the tip of an iceberg, and that behind the scenes there is extensive and ongoing work of issue-raising, and quality articulation. In their different ways, each of the cases exemplifies processes of making features visible and invisible, and it is through such processes that materials are made and *re-made* by being *redefined*, *positioned*, *re-positioned* and *dispositioned*.

There seems to be a recursive relationship between materials and products; materials and products interact and re-make one another. Whereas the previous chapter discussed the seemingly inseparable relation between materials and products, this chapter built on the finding that material capacities do not dictate what the material will be made into. It has shown that products and applications inform the making and qualification of materials. Moreover, in the specific case of bioplastics, the bio-qualities of the materials involved (for instance in packaging) sometimes shape products in specific ways.

This chapter also showed the intricate tension between visibility and invisibility. On the one hand raising an issue and articulating bioplasticness potentially leads to the normalisation of bioplastics and to the category becoming invisible. On the other hand, there are cases in which bioplastics are deliberately invisible, a strategy which forms the material-product relationship but in a way that is not bio. This makes me question the status of the category bioplastics, which might have been a category invented to unite industry efforts and to raise interest in the possibilities that this family of materials hold, but that slowly dissolves in and through the processes of making of materials and of constructing material-product relationships.

The bioplasticness that the materials industry constructs is not the same as the bioplasticness associated with specific qualities valued in marketing and consumer spaces. Bio-identities, as discussed in this chapter, focused on articulating the source or the disposal of bioplastics. The producers and brands making and using bioplastics try to match bioplastics with certain associations, values and networks by making some properties visible and others invisible. The different interests involved each position bioplastic by telling stories which articulate qualities and issues and make them visible; but bioplastics feature in 'more than one' place: the values given to them by different actors, each operating in changing market/product contexts, ensures that bioplastics are continually being reproduced, repositioned and reinvented.

Part of the complexity of bioplastics as a category is that bioplastics are constituted in these very different places, and through recursive dynamics of association and of visibility and invisibility. The relations portrayed in this chapter are meaningful at specific moments in product and material histories. They are provisional and temporally specific. This feature reminds us that there is constant change in the field of bioplastics, as well as in other material and social environments.

CHAPTER 7

DISCUSSION AND CONCLUSIONS

In this thesis I have explored the social and technical processes in and through which bioplastics come to be as they are, and I have done so by focusing on material-product relationships. In the introduction I explained that my interest in the relationship between bioplastics and products originated from the simple observation that 'materials' become involved in daily life and in social practices when they are made into a 'product.' This prompted me to explore the relationship between materials and products more deeply. More specifically, I made the decision to focus on the dynamics and actors involved in transforming materials into products – through processes of production as well as through the work involved in establishing and positioning the qualities of materials within and in relation to products. I have argued that these processes construct material-product relationships.

This close examination of relationships between materials and products represents the novel contribution of this thesis. In this final chapter I elaborate and further reflect on the main insights produced along the way. Very briefly: I showed that materials are continuously in the making. They are repeatedly repositioned in and through the mobilisation of generic categories and formal standards, and via the production and branding arrangements of specific material-product combinations. I also showed that what is taken to be a material or product is relative to the position of the substance/object in the production chain, and that this status varies depending on whether it is viewed by a materials producer, processor or brand. As such, my study is a contribution to sociological research that focuses on the non-human dimension of social worlds, particularly STS and material culture studies. As well as providing new insights regarding the intersection of social, technical and commercial relationships in the making of materials and in how products inform materials and vice versa, my thesis has helped to develop a more subtle analysis of materials and of the social relations through which they are constituted.

In this concluding chapter, I review the route that I followed in my attempt to grasp the dynamic and complex field of bioplastics and the relation between bioplastics and the products into which they are made (Section 7.1). After that, (Section 7.2) I take a step back and reflect on my thesis as a whole, bring the arguments of the chapters together, and offer some further thoughts on how my study extends on the research that initially guided my project. In a separate section (7.3) I revisit the concepts of 'material' and of 'product' that have been developed throughout the thesis. I conclude by reflecting on the changing field of bioplastics and on the insights that my thesis provides for the future studies of materials and for those who are engaged with the making of materials in general, and with innovation and sustainability in particular (Section 7.4).

7.1 The Route Followed

At the time that I started my research I was familiar with the design literature, in which there is a tendency to suppose that materials have given, absolute, fixed and essentially intrinsic properties. I came to see that this is a partial and often misleading understanding of materials, in that it fails to account for the variety and dynamism of the bioplastic sector. For example, such approaches would not be able to grasp the history of Celluloid, which has features as 'a plastic' for most of its career but which has recently been repositioned as a type of bioplastic

– now that this latter category exists. The challenge here is to understand how different properties and values come to be associated with 'the same' material substance in different product arrangements at different periods of time, and to see bioplastics that are themselves sometimes conceptualised as products in their own right.

It was clear that I needed a different conceptualisation of materials if I was to represent and understand these processes. In Chapter 2, I started by comparing approaches in academic design research with those of the social sciences. Within the design literature I found a limited number of theoretical and methodological accounts of materials and the relationship between materials and products. Within the social sciences I found a range of potentially useful concepts, but few directly focusing on this topic. I therefore developed a combination of approaches that are somewhat focused on materials but that also draw on theoretical approaches developed within material culture studies, STS, and marketing and consumer studies – especially those informed by STS.

Linking these ideas together, I was able to study materials as they are constituted within various networks, including production, product development and marketing, and to see materials as enacted in and through these relationships. Barry (2005) in his account of the making of pharmaceutical materials, suggested that even molecular formations are informed by the social and technical environment in which they find their place. In his case such locations included chemistry laboratories, data-keeping infrastructures, pharmaceutical companies, testing schemes, patents and standards infrastructures. Moreover, in his approach and in others like it, the properties of materials are not viewed as being either intrinsic or extrinsic (Callon et al. 2002). Rather, the argument is that the properties of materials are 'elaborated' and 'enacted' within different production and consumption arrangements

(Hawkins, 2013a). In working with these ideas I adopted Callon et al.'s (2002) term 'qualities,' using this to help identify and explore the dynamic 'processes through which qualities are attributed, stabilised, objectified and arranged' (Callon et al., 2002:199). I therefore conceptualised materials as 'active' agents that are 'made' in relation to their social and technical environment, and that also inform these environments. This approach proved to be especially useful in characterising the shifting material relations of bioplastics, this being a field in which definitions are relative, fluid and constantly in the making.

Had I stayed with the limited approach exemplified in the design literature I would not have been able to make these observations or pursue ideas that have been central to the development of this thesis. This theoretical framing informed all aspects of my work, guiding the selection of my respondents, the detail of my interviews and my analysis of the field. Rather than taking the definitions and positions of spokespersons and *Bioplastics Magazine* as definitive and absolute, I was alert to the ongoing and multiple dynamics in which these representations and definitions are situated, and which they help to reproduce.

Recent developments in STS provided a further impetus for my study. Following Woolgar and Leazun's (2013) clarification of an ontology for STS, I share their view that the challenge is not simply one of articulating the multiplicity of perspectives on a given phenomenon, but rather of appreciating the multiplicity of co-existing worlds of which bioplastics are a part. At different points in my account, materials and products belong to different and separate worlds, which are sometimes intersecting. Both materials and products, shape and are shaped by these worlds.

To elaborate, bioplastic materials are sourced from agricultural/natural resources which are synthesized in chemical laboratories, modified to produce different grades/properties (in the research and development facilities of materials producers) and transformed (into a product) throughout various manufacturing processes. The resulting products are in turn developed, produced, marketed, and sold – and are variously shaped by the research and development and marketing and sales departments of brands. Products are subsequently bought, exchanged, used and discarded by consumers. I sought to attend to the movements of 'bioplastics' through some of those different worlds, concentrating especially on points at which materials and their relation to products are co-configured.

I believe the methodological strategies I developed have been uniquely useful for the purposes of my thesis. Since these strategies promise to be of wider relevance for exploring material ontologies in general, I briefly review the key features of my approach. I focused, in particular, on the two processes of 'substituting' materials and 'making materials visible,' and analysed each in detail as a means of 'seeing' how material-product relationships were formed (and reformed).

Substituting, that is replacing one material with another, is one route through which industries launch new materials, typically offering them as alternatives which have certain benefits as compared to existing options. However, as I re-conceptualised it, substituting is not simply a matter of replacing some other material with bioplastics. Rather, substitution is a generative process through which materials are made, insofar as they are compared to previous materials, in terms of quality/qualities and performance, and in relation to the practicalities of manufacturing and production. In taking this approach I conceptualise substitution as both a technical and social process, in which certain aspects become relevant, valued, are made visible and reproduced. By looking at substitution processes in detail, and by showing how bioplastics are compared to and placed among other materials and material-product combinations, I was able to observe different forms of interaction between ‘the material’ and ‘the product’ into which materials are made.

A second methodological strategy was to focus on instances in which material ‘qualities’ are and are not made visible. A focus on ‘visibility’ helped me to see what counts (in the material-product relation) at different moments and also brought into view the different interests that shape materials. By making certain qualities visible and others not, materials producers and brands try to make materials/products relevant to a range of different actors including other producers, consumers, etc. By looking at which particular aspects come to be of importance and which are silenced I was able to identify what counts and for whom, and to observe the processes through which different interests are negotiated.

In this respect the *Bioplastics Magazine* was a particularly useful empirical resource. As I explained in Chapter 3, *Bioplastics Magazine*, the only international trade magazine in the field, represents and seeks to integrate and guide the many different organisations with a stake in the ‘bioplastics’ field. The experiences of ‘pioneering’ materials producers were also critical in that they are and have been actively involved in creating an identity for bioplastic and in building markets for bioplastic material. The products that I examined in detail illustrated something of this variety, being positioned within different industries, within different interest groups and relating to diverse markets and sectors.

What might at first seem to be a rather eclectic range of products and cases is consistent with the development of the field, as revealed in my systematic analysis of *Bioplastics Magazine*. All sources underlined the somewhat random nature of what actually gets made from bioplastics. As we have seen, accidents of history and specific conjunctions of actors and discourses underpin the production of different material-product relations. There is no one driving rationale or logic that guides the development of the sector as a whole. In this context, my strategy of moving between insights generated from an analysis of *Bioplastics Magazine* and of my interviews with pioneering materials producers and organisations involved in shaping a variety of products constituted a plausible and theoretically consistent approach to the challenge of capturing and representing fluctuating relations between materials and products.

Informed by this overall strategy I started examining the categories and formal standards associated with bioplastics and that are central to the definition of the field. As the studies of Bowker and Star (2000:64) and Busch (2011) show, categories and standards do not simply define things: the distinctions involved are actively made by various actors in line with their respective interests. By looking at the formation of categories and formal standards in these terms I was able to identify organisations involved in making the field, including materials producers, converters, consumer organisations, governments, and NGOs. My analysis showed that definitions and categories of materials are negotiated and that this is an ongoing process. Looking at the emergence of categories and standards and at the issues that are made visible in *Bioplastics Magazine* from this perspective showed that materials are not stable but are *continuously in the making.* These movements entail the repositioning of materials in relation to each other and with respect to their symbolic as well as material qualities.

I then followed materials classified as bioplastic (being biobased or biodegradable) into the world of manufacturing. In this context I focused on the practicalities of substitution, and on how new and existing materials are compared. I considered this to be an important route through which material qualities are realised and made real. Although manufacturing might be thought of as a purely technical process organised around clear-cut relations between materials, products, and production equipment, focusing on processes of substitution revealed a more complex picture in which material qualities are elaborated and redefined at every step. Chapter 5 showed that through these social-technical processes, the qualities of materials and their value are constructed in relation to a-) anticipated forms of use and performance, often in relation to the specific conventions/'requirements' of the products they are destined to be made into, b-) qualities of the materials previously used to make the same product, c-) social and technical traditions of the production processes associated with specific product-material combinations, and d-) the further production arrangements that the material is expected to go through depending on the product and its production method.

More specifically, my analysis showed that bioplastic materials are typically *specialised* in their making. This suggests that in at least some instances the material and the product into which it is turned cannot be thought of separately, not even in the production phase of materials themselves, insofar as the details of material production are always oriented towards specific end-products. My analysis also showed that the making of materials is almost always a *compromise*. Instead of arising out of a planned and organised research and development process, the making of bioplastic materials proves to be a *compromise* between actors; materials producers, various converters, brands, products with various physical and symbolic performance expectations, and production and testing equipment.

However, when I looked at specific products (bags, bottles etc.), and explored why bioplastics were made into these objects in particular, I realised that the qualities elaborated in production do not fully determine what materials are made into. This was also a puzzle for the materials producers. The question I posed at the beginning, 'why are bioplastics made into some products and not others' was left partly unanswered.

To get a better understanding of this topic I took advantage of the methodological strategy of attending to what is made visible about bioplastic products. I argued that attending to strategies for making some but not other qualities visible helps show how generic material categories influence (and are influenced by) specific production processes through to particular material-product relationships. Rather than seeing these worlds as disconnected, identifying what is of interest and what is made relevant for whom in each world provided a means of understanding what was going on in the field. Rather than separating the realms of consumption and production, this method allows me to recognise that certain qualities are made visible for certain audiences, and that what I have described as the making of materials continues through the life courses of different products. Exploring the ways in which materials are made visible in product form consequently illuminated the processes through which bioplastic identities are configured.

In Chapter 6, I explored the cases of compostable waste bags, compostable coffee pods, biobased packaging bottles, and the conspicuously bioplastic salad bowl. By following visibility in these rather diverse examples, I recognised some generic patterns. Visibility was achieved in various ways, through using official labels or certificates, or improvised markers, or by making the product itself look different. Different qualities were valued in each material-product combination, yet these qualities always corresponded to some environmental, moral, or economic issue raised and articulated as a problem, in relation to which some quality of bioplastic features as a 'solution.' These product-centric processes in turn feed back, re-shaping material identities and remaking bioplastics through forms of *redefining,* and *positioning-repositioning*. This exercise also showed that invisibility could be equally important in making bioplastic identities, and for the ways in which materials figure in different markets and applications. In some cases, deliberate efforts are made to *disposition* the products and disassociate them from bioplastic-ness. This led to a discussion of whether and how generic categories like bioplastic might evolve and potentially dissolve over time.

Putting the pieces together, my research has shown that materials are continually 'made' in different places, through shifting categories and standards, and through manufacturing and in marketing. By focusing on the relationship between material and product, the thesis challenges representations of materials as inherently fixed, and instead emphasises the point that materials like bioplastics are configured through different worlds – in generic categories and in specific material-product relationships.

The tension between the making of generic as well as product specific qualities reflects the practicalities of making materials. As illustrated above, generic categories are mobilised in configuring specific material-product arrangements. Materials are simultaneously described and positioned in terms of generic categories and specific material-product relationships. In the empirical chapters of the thesis I have tried to capture some of these dynamics, and to bring them together to better understand the co-constitution of both the generic and the specific. Each empirical chapter elaborated on different places and moments in and through which bioplastics come to be. The narrative of these chapters repeats the conventional progression of manufacturing and follows the transformation of materials into product: first focusing on the making of the material, and then its production by material makers, and finally the making of branded products and their positioning in the consumer market. I emphasized as well, however, that the interactions involved in making materials and material-product relations are not as linear as this familiar narrative suggests.

7.2 Drawing Conclusions: Material-Product Relationships

I began by thinking of the relationship between materials and products as one of transformation: hence materials are made into products. Building upon the ideas of Shove et al. (2007), I subsequently re-conceptualised materials as being co-constituted with products. As my study showed, processes of co-constitution take various forms throughout the production processes. Although it is true that materials feature in daily life and in consumer markets not in the abstract but in the form of discrete products, such items are actively involved in 'making' material identities, and in defining material relations and qualities. As such products are both an expression of (often many) materials whilst also having identities of their own. At the same time, materials are also valuable (economic) commodities in their own right. These double processes hint at recursive relationships between materials and products in which they remake one another.

Manufacturing bioplastic materials is so closely allied to the making of specific products that it is better to think of the combination of material-product as the unit of analysis. At the same time, materials have a generic life of their own: aspects of biodegradability or bio-based are defined and certified for the sector as a whole. This suggests that relations between product and material can be in tension, whilst also being co-constitutive. In short my study showed that materials and products are both separate and also intricately interwoven. Furthermore, they keep remaking each other in various ways.

In recognising the complexity of these relationships my research has expanded some of the ideas on which it was initially founded. Whilst Schatzberg (2003) explores aluminium's symbolic values as these change and are formulated across different sectors, he also recognises the persistent salience of qualities like the relative lightness of the material. I also suggest that defining features of bioplastic materials – their sourcing or the way they react to microbial activity – are critical for their valuation as being variously 'bio.' In other words, these qualities were not totally external to bioplastics nor were they imposed on them. This is not to deny the point that 'qualities' are situated and negotiated and that what figures as an important feature for one product in a particular sector, might not be so in another context. For example, compostability has become a positive feature of food packaging, it remains irrelevant in packaging building materials.

Through these and other cases I have developed a deeper understanding of what co-constitution might entail. Building on Shove et al. (2007) I have explored a variety of material-product relations: at certain moments it makes sense to think of 'the material' as something that has distinctive qualities that are imparted to a product and that are remade in specific material-product combinations. Equally, the qualities of materials are elaborated not only in relation to products, but also to production and further production processes as shown through my extensive examination of the water bottle. By comparison, Shove et al.'s chapter on plastics is more limited in scope. I have been able to go further, explaining how the interaction between materials and products is complicated and multiple, being realised through an array of differently dynamic processes.

7.3 The Story Running Alongside: Defining Materials and Products

In order to write this thesis I had to define 'materials' and 'products' at the start, and I have sought to use these terms consistently throughout. As I explained in the introduction, my definitions reflect the conventional progression of manufacturing and their common sense meaning to me as a designer who is routinely involved in turning materials into products. In this study, I used the term 'materials' to refer to a particular molecular arrangement that is the substance from which things are manufactured. I used 'products' to describe things made out of these materials, including the mass-produced, commercial, 'artefactual' units of consumer markets.

However, these definitions soon became problematic, especially for bioplastics, which are themselves the outputs of manufacturing processes and which have economic value in their own right. If products are goods transformed so as to have economic value, bioplastic materials would, by this definition, count as products. This is further complicated because things like 3D printing filament are both a 'product' sold in the marketplace and a 'material' that is used to make products in 3D printing machines in the rapid prototyping laboratory. I want to elaborate on different ways of seeing what a material is and what a product is by referring to the terminology adopted by the materials producers with whom I spoke. These people talked about their materials as 'products' and products as 'applications.' From the perspective of materials producers, bioplastics are sourced from plant 'raw material' and are produced by synthesis into granules, which have an economic value and are sold. However, for converters or brands, these granules are then the 'raw materials' with which things are produced. In the case of bioplastics, the status of material and product are constantly changing. For example, products become materials for compost, and compost is then material for planting, and the plant is then material from which bioplastic granules can be synthesised.

My thesis shows that for bioplastics the terms ‘material’ and ‘product’ are different, but also intricately interconnected. In addition, what constitutes a product is relative to where one stands in the production process.

Here I want to refer back to the special issue of the journal *Archaeological Dialogues* I mentioned in the introduction. In his article in this special issue, Ingold (2007a) raises a set of questions and critiques the attention given to materiality, though not to the materials on which concepts of materiality depend. Ingold (2007a) suggests that to be able to talk about materials we have to see them in the ‘raw.’ He therefore invites readers to take a pebble from the garden and get in touch with the ‘raw’ material, in order to understand materiality. Tilley (2007) and Miller (2007) in this same issue, highlight the artefactual nature of the carefully chosen pebble. Miller (2007:27) also wonders ‘why Ingold seems to want to privilege a stone in his eloquent discussion of the nature of material over a mobile phone and plastic.’ In this series of writings, understanding materials seem to be about contemplating their natural or artefactual aspects. My contribution to this discussion is to suggest that both these *categories,* the ‘material’ and the ‘product’ are essentially *cultural*.

7.4 Concluding Remarks

My thesis has sought to represent the complexity of the bioplastics field in terms of its multiplicity, fragmented industries, opportunistic pace and dynamism. As I learned more, rather than developing a more complete sense of the field I felt that it became more elusive.

Bioplastics have not yet lived up to the expectation of being the future of plastic, nor have they replaced oil based plastics on any scale. According to 2014 reports of the Nova Institute bioplastics represent about 2 percent of the total traditional plastic market. Even so, steady growth and projections of acceleration continue to attract political interest, funding for research and development and investment in the sector. Compared to what was available at the beginning of my study there is now much information online. The *Bioplastics Magazine's* website is more developed. It now includes a daily news section, and biweekly newsletters both of which suggest that rapid growth is continuing. New players are also entering the field and becoming prominent, for example FKuR, with their bio-flex material,[152] and BASF with their commercials broadcasted on television.[153]

It is impossible to keep up with these developments. Rather than aiming to produce a momentarily comprehensive map of the field, my method has been to explore cases and examples which provide insight into relevant relationships, captured at one moment in time and at one point in the ongoing development of the bioplastic sector. Although my thesis is rich with examples, I left out many more that either addressed the same topics in less salient or compelling ways, or whose inclusion would call for further complex description but without helping to make sense of an already fragmented field and without adding to my analysis of the processes and relationships involved.

---

[152] Advertising on *Bioplastics Magazine*, for example main page of the magazine http://www.bioplasticsmagazine.com/en/index.php accessed on 2nd Sept 2015.

[153] Television commercial of BASF can be view from the website of BASF: http://we-create-chemistry.basf.com/en/resources-environment-climate/film on 14th Sept 2015.

As is now obvious the thesis makes no attempt to provide a complete and exact account of how bioplastics come to be: indeed one conclusion is that it would be impossible to produce any one such account. Instead, my thesis showed that the making of materials is a constant process of remaking and reproduction. I have argued that there are insights arising from this analysis that are of wider relevance within studies of science and technology and the social sciences more broadly.

Clearly, some of the conclusions of this study apply to materials in general. All materials are situated in terms of generic categories and all also exist in specific material-product combinations. It is through these dynamic processes of positioning, development and comparison that the qualities of materials are temporarily stabilised and constantly challenged. I suggest that my methodological strategy of focusing on forms of substitution, and on forms of making qualities visible could be usefully applied in other situations and that such methods reveal the social and technical making of materials. That said the nature of these processes, and the details explored in this thesis, are specific to bioplastics, and to a particular moment in their development within and alongside a range of environmental concerns. For example, bioplastics need to be identified as such and rendered obvious because their defining bio-qualities are often invisible to the naked eye. This feature adds to the complexity of material-making, and also calls for specific and dedicated attention if bioplastic is to acquire an identity in an already crowded material world.

The green or environmentally friendly positioning of bioplastic provides an important context both for the sector as a whole and for my study. However, my analysis complicates any such simple association and in so doing complicates accounts of the relation between sustainability, sustainable materials and innovation. First of all, while the ‘bio’, green and environmental positioning has undoubtedly informed the identity of bioplastics, in some cases, this is not the most important aspect. Instead bioplastics may be 'better' because of other qualities, such as permeability in fresh food packaging. Moreover, I showed that the value of bioplastics is not only about being 'bio' or the cost compared to oil based alternatives. Instead, and as this thesis has shown, discourses of sustainability are as complex as bioplastics themselves. Bioplastic is not one type of material used in the making of products. Instead, bioplastics are complex outcomes of multiple social-material relations formed along what is in many ways a problematic path, weaving through various industries, social groups, value propositions and social and technical arrangements of production and closely coupled with the lives of a somewhat arbitrary set of products. This is clearly not a straightforward narrative in which 'good' environmentally friendly products are positioned in the market. Nor is it one in which popular or political environmental concerns are simply given material expression.

BIBLIOGRAPHY

Aguado, J., Serrano, D.P., and Clark, J.H. (1999). Introduction. In J. Aguado, and D. P. Serrano (Eds.), *Feedstock recycling of plastic wastes* (pp. 1-29).

Akrich, M. (1992). The de-scription of technical objects. In W.E. Bijker, and J. Law (Eds.), *Shaping technology/Building society: Studies in sociotechnical change* (pp. 205-224). Cambridge, MA: MIT Press.

Álvarez-Chávez, C.R., Edwards, S., Moure-Eraso, R., and Geiser, K. (2012). Sustainability of bio-based plastics: general comparative analysis and recommendations for improvement. *Journal of Cleaner Production, 23*(1), 47-56.

Appadurai, A. (1986). Introduction: Commodities and the politics of value. In A. Appadurai (Ed.), *The Social Life of Things: Commodities in Cultural Perspective* (pp. 3-63). Cambridge: Cambridge University Press.

Araujo, L., Finch, J.H., and Kjellberg, H. (2010). *Reconnecting marketing to markets*. Oxford: Oxford University Press.

Ashby, M., and Johnson, K. (2002). *Materials and Design: The Art and Science of Material Selection in Product Design*. Burlington, MA: Butterworth-Heinemann.

Banerjee, M., and Miller, D. (2003). *The Sari*. Oxford: Berg.

Bardsley, G., and Corke, C. (2006). *Making Cars at Longbridge: 100 Years in the Life of a Factory*. Stroud: Tempus.

Bardsley, G., and Laing, S. (1999). *Making Cars at Cowley: From Morris to Rover*. Stroud: Sutton Publishing.

Barry, A. (2005). Pharmaceutical matters: The invention of informed materials. *Theory, Culture & Society, 22*(1), 51-69.

Barthes, R. (2000). *Mythologies*. (A. Lavers, Trans.). London: Vintage Books. (Original work published in 1957).

Bennett, J. (2004). The force of things steps toward an ecology of matter. *Political Theory, 32*(3), 347-372.

Bennett, J. (2007). Edible matter. *New Left Review, 45*, 133-145. Retrieved from: http://www.newleftreview.org/?page=article&view=2674.

Bennett, J. (2010). *Vibrant Matter: A Political Ecology of Things*. Durham, NC: Duke University Press.

Bensaude-Vincent, B., and Stengers, I. (1996). *A History of Chemistry*. Cambridge, MA: Harvard University Press.

Bensaude-Vincent, B. (2001a). A genealogy of the increasing gap between science and the public. *Public Understanding of Science, 10*(1), 99-113.

Bensaude-Vincent, B. (2001b). The construction of a discipline: Materials science in the United States. *Historical Studies in the Physical & Biological Sciences, 31*(2), 223-248.

Bensaude-Vincent, B., Arribart, H., Bouligand, Y., and Sanchez, C. (2002). Chemists and the school of nature. *New Journal of Chemistry, 26*(1), 1-5.

Bensaude-Vincent, B. (2009). A historical perspective on science and its 'others'. *Isis, 100*(2), 359-368.

Bensaude-Vincent, B., Loeve, S., Nordmann, A., & Schwarz, A. (2011). Matters of interest: the objects of research in science and technoscience. *Journal for General Philosophy of Science, 42*(2), 365-383.

Beretta, M. (1993). *The Enlightenment of Matter: The Definition of Chemistry from Agricola to Lavoisier*. Uppsala studies in history of science, 15. Canton, MA: Science History Publications.

Bijker, W.E. (1992). The social construction of fluorescent lighting, or how an artefact was invented in its diffusion stage. In W.E. Bijker, and J. Law (Eds.), *Shaping technology/Building society: Studies in sociotechnical change* (pp. 75-102). Cambridge, MA: MIT Press.

Bijker, W.E. (1995). *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*. Cambridge, MA: MIT press.

Bijker, W., and Law, J. (1992). *Shaping Technology/Building Society: Studies in Sociotechnical Change*. Cambridge, MA: MIT Press.

Bioplastics Magazine (Vols. 1-42). Michael Thielen (Ed.). Germany: Polymedia Publisher.

Bouquet, T., and Ousey, B. (2009). *Cold Steel: Lakshmi Mittal and the Multi-billion-dollar Battle for a Global Empire*. London: Abacus.

Bowker, G.C., and Star, S.L. (2000). *Sorting Things out: Classification and its Consequences.* Cambridge, MA: MIT Press.

Buchli, V. (Ed.). (2002). *The Material Culture Reader*. Oxford: Berg.

Busch, L. (2011). *Standards: Recipes for Reality*. Cambridge, MA: MIT Press. Retrieved from http://lib.myilibrary.com.ezproxy.lancs.ac.uk/Open.aspx?id=330282.

Butler, M.F. (2011). *Bio-Plastics: A Unilever Perspective* [PDF document]. Presented at: The industrial use of bio-based plastics conference, Sheffield (2011, October 6th). Retrieved from SCI website: http://www.soci.org/~/media/Files/Conference%20Downloads/2011/BioPlastics%202011/BioPlastics_2011_BioPlastics_A_Unilever_Perspective_Mike_Butler.ashx.

Callon, M., Méadel, C., and Rabeharisoa, V. (2002). The economy of qualities. *Economy and Society, 31*(2), 194-217.

Callon, M., and Muniesa, F. (2005). Peripheral vision: Economic markets as calculative collective devices. *Organization Studies, 26*(8), 1229-1250.

Candlin, F., and Guins, R. (Eds.). (2009). *The Object Reader.* In-sight: Visual Culture. Oxon, NY: Routledge.

Cassell, M. (1986). *The Readymixers: The Story of RMC, 1931 to 1986.* Pencorp management series. London: Pencorp.

Certeau, M. (2002). *The Practice of Everyday Life.* (S. Rendall, Trans.). Berkeley, CA: University of Carolina Press. (Original work published 1988).

Chaney, D. (2002). *Cultural Change and Everyday Life*. Basingstoke: Palgrave.

Chappell, V. (1973). Matter. *The Journal of Philosophy, 70*(19), 679-696.

Chappells, H., and Shove, E. (1999). The dustbin: A study of domestic waste, household practices and utility services. *International Planning Studies, 4*(2), 267-280.

Clarke, A.J. (1999). *Tupperware: The Promise of Plastic in 1950s America*. Washington, DC: Smithsonian Institution Press.

Clarke, A.J. (Ed.). (2010). *Design Anthropology: Object Culture in the 21st Century*. Edition angewandte. New York: Springer.

Cochoy, F. (2005). A brief history of 'customers', or the gradual standardization of markets and organizations. *Sociologie du Travail, 47*, e36-e56.

Cochoy, F. (2007). A sociology of market- things: on tending the garden of choices in mass retailing. *The Sociological Review, 55*(s2), 109-129.

Cochoy, F. (2008). Calculation, qualculation, calqulation: shopping cart arithmetic, equipped cognition and the clustered consumer. *Marketing Theory, 8*(1), 15-44.

Cochoy, F. (2012). *Curiosity, packaging, and the economics of surprise*. (A. Colin, Trans.). Excerpt from F. Cochoy, De la curiosité, l'art de la séduction marchande. (Original work published 2011). Retrieved from: http://www.charisma-network.net/markets/curiosity-packaging.

Cochoy, F. (2014). Consumers at work, or curiosity at play? Revisiting the prosumption/value cocreation debate with smartphones and two-dimensional bar codes. *Marketing Theory, 15*(2), 133-153.

Costall, A., and Dreier, O. (Eds.). (2006). *Doing Things with Things: The Design and Use of Everyday Objects*. Ethnoscapes. Aldershot: Ashgate.

Dant, T. (1999). *Material Culture in the Social World: Values, Activities, Lifestyles*. Buckingham: Open University Press.

David, S., and Ting, K. (2013). Green illusions: the dirty secrets of clean energy and the future of environmentalism. *International Journal of Environmental Studies, 70*(5).

Davies, P. (2013, July 1st). *Chemical business focus: A monthly roundup and analysis of the key factors shaping world chemical markets* [PDF document]. Retrieved from Tecnon OrbiChem website: http://www.orbichem.com/userfiles/Promotions/bm_000.pdf.

Davison, J. (2012). Icon, Iconography, Iconology: Banking, branding and the Bowler hat. In F.R. Puyou, P. Quattrone, C. Mclean, and N. Thrift (Eds.), *Imagining organizations: Performative imagery in business and beyond*. (pp. 152-172). Routledge Studies in Management, Organizations and Society. New York, NY: Routledge.

De Landa, M. (n.d.). *Uniformity and variability: an essay in the philosophy of matter*. Retrieved from http://www.t0.or.at/delanda/matterdl.htm.

Denscombe, M. (2010). *The good research guide: For small-scale social research projects*. (4th ed.). Open UP study skills. Maidenhead: Open University Press.

DiGregorio, B.E. (2009). Biobased performance bioplastic: Mirel. *Chemistry & Biology, 16*(1), 1-2.

DuBois, J., and John, F.W. (1981). *Plastics*. (6th ed.). New York: Van Nostrand Reinhold.

Earle, J.B.F. (1971). *A Century of Road Materials: The History of the Roadstone Division of Tarmac Ltd.* Oxford: Blackwell.

Evans, D. (2012). Beyond the throwaway society: ordinary domestic practice and a sociological approach to household food waste. *Sociology, 46*(1), 41-56.

Fenichell, S. (1996). *Plastic: The Making of a Synthetic Century.* New York: HarperCollins.

Fiell C. and Fiell P. (2010). *Plastic Dreams: Synthetic Visions in Design*. London: Fiell Publishing.

Fisher, T. (2004). What we touch, touches us: Materials, affects, and affordances. *Design Issues, 20*(4), 20-31.

Fisher, T., and Shipton, J. (2010). *Designing for Re-use: The Life of Consumer Packaging*. London: Earthscan.

Fiske J. (1992). Cultural studies and the culture of everyday life. In L. Grossberg, C. Nelson, and P.A. Treichler (Eds.), *Cultural Studies*, (pp. 154–173). New York, NY: Routledge. Retrieved from: http://www.hu.mtu.edu/~jdslack/readings/CSReadings/Fiske_Cultural_Studies_Culture_Everyday_Life.pdf.

Foodservice Director; Jan 15, 2009; 22(1), p12, Pro-Quest Business Collection, 'Government Center Cafeteria to Use Bio-plastic Containers.'

Freinkel, S. (2011). *Plastic: A Toxic Love Story*. Melbourne: Text Publishing.

Gabrys, J., Hawkins, G., and Michael, M. (Eds.). (2013). *Accumulation: The material politics of plastic*. Culture, economy and the social. New York, NY: Routledge.

Garrow, D., and Shove, E. (2007). Artefacts between disciplines: The toothbrush and the axe. *Archaeological Dialogues, 14*(2), 117-131.

Gibson, J.J. (1968). *The Senses Considered as Perceptual Systems*. L. Carmichael (Ed.). London: Allen & Unwin.

Gibson, J.J. (1977). The theory of affordances. In J.J. Gieseking, W. Mangold, C. Katz, S. Low, and S. Saegert (Eds.), *The People, Place, and Space Reader*, (pp. 56-60). New York, NY: Routledge.

Gibson, J.J. (1986). *The Ecological Approach to Visual Perception*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Gordon, I.E. (2004). *Theories of Visual Perception*. Hove: Psychology Press.

Grodnik, A., and Conroy, M.E. (2007). Fair Trade coffee in the United States: Why companies join the movement. In L.T. Raynolds, D. Murray, and J. Wilkinson (Eds.), *Fair trade: The challenges of transforming globalization* (pp. 83-102). New York, NY: Routledge.

Haggerty, K.D., and Ericson, R.V. (Eds.). (2006). *The New Politics of Surveillance and Visibility*. Green College thematic lecture series. Toronto, Ont.: University of Toronto Press.

Handley, S. (1999). *Nylon: The Story of a Fashion Revolution*. Baltimore: Johns Hopkins University Press.

Harper, D. (1992). *Working Knowledge: Skill and Community in a Small Shop*. Berkeley: University of California Press.

Hawkins, G. (2001). Plastic bags: living with rubbish. *International Journal of Cultural Studies, 4*(1), 5–23.

Hawkins, G. (2009). The politics of bottled water: assembling bottled water as brand, waste and oil. *Journal of Cultural Economy, 2*(1-2), 183-195.

Hawkins, G. (2011a). Making water into a political material: the case of PET bottles. *Environment and Planning A, 43*, 2001-2006.

Hawkins, G. (2011b). Packaging water: plastic bottles as market and public devices. *Economy and Society, 40*(4), 534-552.

Hawkins, G. (2013a). Made to be wasted: PET and topologies of disposability. In Gabrys, J., Hawkins, G., and Michael, M. (Eds.). (2013). *Accumulation: The material politics of plastic*. Culture, economy and the social (pp. 49-67). New York, NY: Routledge.

Hawkins, G. (2013b). The performativity of food packaging: market devices, waste crisis and recycling. *The Sociological Review, 60*(S2), 66–83.

Henare, A., Holbraad, M., and Wastell, S. (Eds.). (2007). *Thinking through Things: Theorising Artefacts Ethnographically*. London: Routledge.

Höfer, R., and Bigorra, J. (2008). Biomass-based green chemistry: sustainable solutions for modern economies. *Green Chemistry Letters and Reviews, 1*(2), 79-97.

Hoover, F.G. (1955). *Fabulous Dustpan: The Story of the Hoover*. Cleveland: The World Publishing Company.

Howes, P., and Laughlin, Z. (2012). *Material Matters: New Materials in Design*. London: Black Dog.

Hughes, A., and Reimer, S. (Eds.). (2004). *Geographies of Commodity Chains*. Routledge Studies in Human Geography. London: Routledge.

Ingold, T. (2006a). Rethinking the animate, re-animating thought. *Ethnos: Journal of Anthropology, 71*(1), 9-20.

Ingold, T. (2006b). Up, across and along. *Studies in Environmental Aesthetics and Semiotics, 5*, 21-36. Retrieved from: http://www.eki.ee/km/place/pdf/kp5_02_ingold.pdf.

Ingold, T. (2007a). Materials against materiality. *Archaeological Dialogues, 14*(01), 1-16.

Ingold, T. (2007b). Earth, sky, wind, and weather. *Journal of the Royal Anthropological Institute, 13*(S1), S19-S38.

Ingold, T. (2008). Bindings against boundaries: entanglements of life in an open world. *Environment and Planning A, 40*(8), 1796-1810.

Ingold, T. (2009). The textility of making. *Cambridge Journal of Economics, 34*, 91–102.

Ingold, T. (2010). Bringing Things to Life: Creative Entanglements in a World of Materials. In: *ESRC National Centre for Research Methods NCRM, Working Paper Series*, Working Paper #15. Retrieved from NCRM website: http://eprints.ncrm.ac.uk/1306/1/0510_creative_entanglements.pdf

Ingram, J., Shove, E., and Watson, M. (2007). Products and Practices: Selected Concepts from Science and Technology Studies and from Social Theories of Consumption and Practice. *Design Issues, 23*(2), 3-16.

Johnson, J. (1988). Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer. *Social Problems, 35*(3), Special Issue: The Sociology of Science and Technology, 298-310. Oxford: University of California Press on behalf of the Society for the Study of Social Problems. Retrieved from: http://www.jstor.org/stable/800624.

Karana, E. (2012). Characterization of 'natural' and 'high-quality' materials to improve perception of bio-plastics. *Journal of Cleaner Production, 37*, 316-325.

Karana, E., Hekkert, P., and Kandachar, P. (2008). Material considerations in product design: A survey on crucial material aspects used by product designers. *Materials & Design, 29*(6), 1081-1089.

Karana, E., Hekkert, P., and Kandachar, P. (2009). Meanings of materials through sensorial properties and manufacturing processes. *Materials & Design, 30*(7), 2778-2784.

Karana, E., Pedgley, O, and Rognoli, V. (Eds.). (2014). *Materials Experience: Fundamentals of Materials and Design*. Oxford: Butterworth-Heinemann.

Katz, S. (1978). *Plastics: Design and Materials*. London: Studio Vista.

Knappett, C. (2007). Materials with materiality? *Archaeological Dialogues, 14*(01), 20-23.

Knight, P.T. (2002). *Small-scale research: Pragmatic inquiry in social science and the caring professions*. London: SAGE.

Kopytoff, I. (1986). Cultural biography of things: Commoditization as a process. In A. Appadurai (Ed.), *The Social Life of Things: Commodities in Cultural Perspective* (pp. 64-91). Cambridge: Cambridge University Press.

Kotler, P., Scheff, J., and Americans for the Arts. (1997). *Standing Room Only: Strategies for Marketing the Performing Arts*. Boston, MA: Harvard Business School Press.

Kuechler, S. (2010). Materials and Design. In A.J. Clarke (Ed.), Design Anthropology: Object Culture in the 21st Century, Edition Angewandte, (pp. 130-141). New York, NY: SpringerWien.

Lanning, G., Peaker, C., Webb, C., White, R., and Television History Workshop. (1985). *Making Cars: A History of Car Making in Cowley by the People Who Make the Cars*. History workshop series. London; Boston: Routledge & Kegan Paul.

Latimer, J., and Miele, M. (2013). Naturecultures? Science, affect and the non-human. *Theory, Culture & Society, 30*(7-8), 5-31.

Latour, B. (1994). Where are the Missing Masses? The Sociology of a Few Mundane Artifacts. In: W. Bijker, J. Law, (Eds.), *Shaping technology/Building society: Studies in sociotechnical change* (pp. 225-258). Cambridge, MA: MIT Press.

Latour, B. (1995). Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer. In Star, S.L. (Ed.), *Ecologies of knowledge: Work and politics in science and technology*. Binghamton: State University of New York Press.

Latour, B. (1999). *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, MA: Harvard University Press.

Latour, B. (2000). When things strike back: a possible contribution of ‘science studies’ to the social sciences. *British Journal of Sociology, 51*(1), 107–123.

Latour, B. (2005). From realpolitik to dingpolitik: An introduction to making things public. In: B. Latour, P. Weibel (Eds.), *Making things public: Atmospheres of democracy*, (pp. 14-44). Cambridge, MA: MIT Press.

Lau, G. F. (2010). The work of surfaces: object worlds and techniques of enhancement in the ancient Andes. *Journal of Material Culture, 15*(3), 259-286.

Law, J. (2004). *After Method: Mess in Social Science Research*. Oxon: Routledge.

Law, J. (2008, April 9). *The Materials of STS* [PDF document]. Retrieved from: http://www.heterogeneities.net/publications/Law2008MaterialsofSTS.pdf.

Lefteri, C. (2006). *Materials for Inspirational Design*. Mies, Switzerland: RotoVision.

Lefteri, C. (2008). *The Plastics Handbook*. Mies, Switzerland: RotoVision.

Leonardi, P.M., and Barley, S.R. (2008). Materiality and change: Challenges to building better theory about technology and organizing. *Information and Organization, 18*(3), 159-176.

Leslie, S.W. (2011). The strategy of structure: Architectural and managerial style at Alcoa and Owens-Corning. *Enterprise and Society, 12*(4), 863-902.

Lubick, N. (2007). Plastics from the bread basket. *Environmental Science & Technology, 41*(19), 6639-6640.

Lubove, S. (1999, February 8). Good intentions. *Forbes, 163*(3), 62-64. Retrieved from http://www.forbes.com/global/1999/0208/0203051a.html.

Lucas, G. (2002). Disposability and dispossession in the twentieth century. *Journal of Material Culture, 7*(1), 5-22.

Lynch, M. (2013). Ontography: Investigating the production of things, deflating ontology. *Social Studies of Science, 43*(3).

Manzini, E. (1986). *The Material of Invention*. (A. Shugaar, Trans.) Cambridge, MA: MIT Press. (Original work published 1986).

Marres, N., Rogers, R. (2005). Recipe for Tracing the Fate of Issues and Their Publics on the Web. In B. Latour and P. Weibel (Eds.), *Making things public: Atmospheres of democracy*, (pp. 922-935). Cambridge, MA: MIT Press.

Marres, N. (2007). The issues deserve more credit pragmatist contributions to the study of public involvement in controversy. *Social Studies of Science, 37*(5), 759-780.

Marres, N. (2008). The making of climate publics: eco-homes as material devices of publicity. *Distinktion: Scandinavian Journal of Social Theory, 9*(1), 27-45.

Marres, N. (2010). Frontstaging Nonhumans: Publicity as a Constraint on the Political Activity of Things. In B. Braun, and S.J. Whatmore (Eds.), *Political matter: Technoscience, democracy, and public life*, (pp. 177-210). Minneapolis, MN: Minnesota University Press. Retrieved from http://research.gold.ac.uk/6229/.

Marres, N. (2012a). *Material Participation: Technology, the Environment and Everyday Publics*. Hampshire: Palgrave Macmillan.

Marres, N. (2012b). On some uses and abuses of topology in the social analysis of technology (or the problem with smart meters). *Theory, Culture & Society, 29*(4-5), 288-310.

Marres, N. (2013). Why political ontology must be experimentalized: On ecoshowhomes as devices of participation. *Social studies of Science, 43*(3), 417-443.

Marres, N. (2014). The environmental teapot and other loaded household objects: Reconnecting the politics of technology, issues and things. In: P. Harvey et al. (Eds.), *Objects and materials: A Routledge companion*, (pp. 260-271). London and New York: Routledge.

Meikle, J. (1997a). *American plastic: A cultural history*. New Brunswick, N.J.: Rutgers University Press.

Meikle, J. L. (1997). Material doubts: the consequences of plastic. *Environmental History, 2*(3), 278-300. Retrieved from http://envhis.oxfordjournals.org/content/2/3/278.full.pdf on 12/10/2015.

Merriam, J., British Xylonite Company, and Bakelite Xylonite Ltd. (1976). *Pioneers in Plastic*. Ipswich: East Anglian Magazine.

MacKenzie, D. (2012). Visible, tradeable carbon: how emissions markets are constructed. In F.R. Puyou, P. Quattrone, C. Mclean, and N. Thrift (Eds.), *Imagining organizations: Performative imagery in business and beyond* (pp. 53-79). Routledge Studies in Management, Organizations and Society. New York, NY: Routledge.

Miele, M. (2011). The taste of happiness: Free-range chicken. *Environment and Planning A, 43*(9), 2076-2090.

Miller, D. (Ed.). (2005). *Materiality*. Durham, NC: Duke University Press.

Miller, D. (2007). Stone Age or Plastic Age? *Archaeological Dialogues, 14*(1), 23-27.

Miller, D. (2008). *The Comfort of Things*. Cambridge: Polity Press.

Miller, D. (2010). *Stuff*. Cambridge: Polity Press.

Miller, D. (2011). *Tales from Facebook*. Cambridge: Polity Press.

Misa, T. (1995). *A Nation of Steel: The Making of Modern America, 1865-1925*. Johns Hopkins studies in the history of technology. Baltimore, MD: Johns Hopkins University Press.

Mohantya, A.K., Misraa, M., and Hinrichsen, G. (2000). Biofibres, biodegradable polymers and biocomposites: An overview. *Macromolecular Materials and Engineering, 276*(1), 1-24.

Molotch, H. (2003). *Where Stuff Comes From: How Toasters, Toilets, Cars, Computers, and Many Others Things Come to Be as They Are*. New York, NY: Routledge.

Murray, D.L., and Raynolds, L.T. (2007). Globalization and its antinomies: negotiating a Fair Trade movement. In L.T. Raynolds, D. Murray, and J. Wilkinson (Eds.), *Fair Trade: The challenges of transforming globalization* (pp. 3-14). New York, NY: Routledge.

Naitove, M.H. (2012, April). Bioplastics Are Breaking Out of Their 'Green' Niche [Conference Report]. *Plastics Technology, 58*(4), 13-17, 58-62. Retrieved from Plastics Technology website: http://www.ptonline.com/articles/conrerence-report-bioplastics-are-breaking-out-of-their-green-niche.

NatureWorks LLC (2009, October). *The Ingeo™ Journey*. Retrieved from NatureWork LLC website: http://www.natureworksllc.com/~/media/News_and_Events/NatureWorks_TheIngeoJourney_pdf.pdf.

Ndiaye, P. (2007). *Nylon and Bombs: Dupont and the March of Modern America*. (E. Forster, Trans.). Studies in industry and society. Baltimore, MD: Johns Hopkins University Press. (Original work published 2001).

Norman, D. (2004). *Affordances and design*. Unpublished manuscript. Retrieved from http://citeseerx.ist. psu.edu/viewdoc/download?.

Patel, R. (2009). *The value of nothing: How to reshape market society and redefine democracy*. London: Portobello.

Pedgley, O. (2009). Influence of stakeholders on industrial design materials and manufacturing selection. *International Journal of Design, 3*(1), 1-15.

Pinch, T.J., Bijker, W.E. (1984). The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science, 14*(3), 399-441.

Plastics News (2003, June 16). *Supplier News*. Retrieved from Plastics News website: http://www.plasticsnews.com/article/20030616/NEWS/306169973/supplier-news.

Reader, W.J. (1976). *Metal Box: A History*. London: Heinemann.

Ren, X. (2003). Biodegradable plastics: a solution or a challenge? *Journal of Cleaner Production, 11*(1), 27-40.

Roberts, J. A. (2010). Reflections of an Unrepentant Plastiphobe: Plasticity and the STS Life. *Science as Culture, 19*(1), 101-120.

Rogers, R., and Marres, N. (2000). Landscaping climate change: A mapping technique for understanding science and technology debates on the World Wide Web. *Public Understanding of Science, 9*(2), 141-163.

Rossi, M., and Lent, T. (2006, September). *Creating Safe and Healthy Spaces: Selecting Materials that Support Healing*. Concord, CA: The Center for Health Design. Retrieved from The Center for Health Design website:https://www.healthdesign.org/chd/research/creating-safe-and-healthy-spaces-selecting-materials -support-healing.

Royte, E. (2008). *Bottlemania: How Water Went on Sale and Why We Bought It*. New York, NY: Bloomsbury.

Sayes, E. (2014). Actor–Network theory and methodology: Just what does it mean to say that nonhumans have agency? *Social Studies of Science, 44*(1), 134-149.

Scerri, A. (2013). Green citizenship and the political critique of injustice. *Citizenship Studies, 17*(3-4), 293-307.

Schatzberg, E. (2003). Symbolic culture and technological change: The cultural history of aluminum as an industrial material. *Enterprise and Society, 4*(2), 226-271.

Schatzki, T. (2010). Materiality and social life. *Nature and Culture, 5*(2), 123-149.

Shaw, I. (2010). *Making dental commodities: A socio-technical analysis of commercial practice* (Doctoral dissertation). Retrieved from Lancaster University theses repository. (T/4975).

Shove, E. (2003). Users, technologies and expectations of comfort, cleanliness and convenience. *Innovation: The European Journal of Social Science Research, 16*(2), 193-206.

Shove, E., Watson, M., Hand, M., and Ingram, J. (2007). *The design of everyday life*. Cultures of Consumption Series. Oxford: Berg.

Sparke, P. (Ed.). (1994). *The Plastics Age: From Bakelite to Beanbars and Beyond*. Woodstock, NY: The Overlook Press.

Spurling, N. (2010). *Authors of our own lives?: Individuals, institutions and the everyday practice of sociology* (Doctoral dissertation). Retrieved from Lancaster University theses repository. (T/5132).

Stevens, E. S. (2002). *Green Plastics: An Introduction to the New Science of Biodegradable Plastics*. Princeton, NJ: Princeton University Press.

Strasser, S. (1999). *Waste and Want: A Social History of Trash*. New York, NY: Metropolitan Books.

Tabone, M.D., Cregg, J.J., Beckman, E.J., and Landi, A.E. (2010). Sustainability metrics: Life cycle assessment and green design in polymers. *Environmental Science & Technology, 44*(21), 8264–8269.

Talbot, J. M. (1997). Where does your coffee dollar go?: The division of income and surplus along the coffee commodity chain. *Studies in comparative international development, 32*(1), 56-91.

Thielen, M. (2012). *Bioplastics: Basics applications markets*. Mönchengladbach: Polymedia.

Thomas, N. (1991). *Entangled Objects: Exchange, Material Culture, and Colonialism in the Pacific*. Cambridge, MA: Harvard University Press.

Tilley, C. (Ed.). (1990). *Reading material culture: Structuralism, hermeneutics, and post-structuralism*. Social archaeology. Oxford, UK; Cambridge, MA: B. Blackwell.

Tilley, C. (2004). *The Materiality of Stone: Explorations in Landscape Phenomenology*. New York, NY: Berg.

Tilley, C. (2007). Materiality in materials. *Archaeological Dialogues, 14*(1), 16-20.

Tilley, C., Keane, W., Küchler, S., Rowlands, M., and Spyer, P. (Eds.). (2006). *Handbook of Material Culture*. London: SAGE.

Trentmann, F. (2009). Materiality in the future of history: Things, practices, and politics. *The Journal of British Studies, 48*(2), 283-307.

Tweedale, G. (2000). *Magic Mineral to Killer Dust: Turner & Newell and the Asbestos Hazard*. Oxford: Oxford University Press.

Unilever N.V. (2009). *Sustainable packaging?* [PDF document]. Retrieved from: https://www.unilever.com/Images/sd_sustainable-packaging--2009-_tcm13-387437_tcm244-409779_1.pdf on 12/10/2015.

Van der Kamp, M. (2011). *Enacting standards in organic agriculture*. (Doctoral dissertation). Retrieved from Lancaster University, theses repository. (Source record number: 2173914340001221).

Van Kesteren, I. E. H., Stappers, P. J., and de Bruijn, J. C. M. (2007). Materials in product selection: Tools for including user-interaction aspects in materials selection. *International Journal of Design, 1*(3), 41-55.

Vannini P., and Taggart J. (2013). Domestic lighting and the off-grid quest for visual comfort. *Environment and Planning D: Society and Space, 31*(6), 1076-1090.

Verbeek, P. (2005). *What Things Do: Philosophical Reflections on Technology, Agency, and Design*. (R.P. Crease, Trans.). University Park, PA: Pennsylvania State University Press. (Original work published 2000).

Vink, E.T.H., Davies, S., and Kolstad, J.J. (2010, August). The eco-profile for current Ingeo® polylactide production. *Industrial Biotechnology, 6*(4), 211-224. New Rochelle, NY: Mary Ann Liebert, Inc., publishers.

Wahlberg, H. (1999). *Everyday Elegance: 1950s Plastics Design* (2nd ed.). Atglen, PA: Schiffer Publishing.

Walker, G., and Shove, E. (2007): Ambivalence, sustainability and the governance of socio-technical transitions. *Journal of Environmental Policy & Planning, 9*(3-4), 213-225.

Waltz, E. (2008). Do biomaterials really mean business? *Nature biotechnology, 26*(8), 851-853.

Wang, S. (2007). *Becoming Taiwanese: Everyday practices and identity transformation*. (Doctoral dissertation). Retrieved from Lancaster University theses repository. (T/4415).

Wastiels, L., and Wouters, I. (2012). Architects' considerations while selecting materials. *Materials and Design, 34*, 584–593.

Webb, K. (2005). Signs Are Not the Garb of Meaning: On the Social Analysis of Material Things. In Miller, D. (Ed.). *Materiality* (pp. 182-205). Durham, NC: Duke University Press.

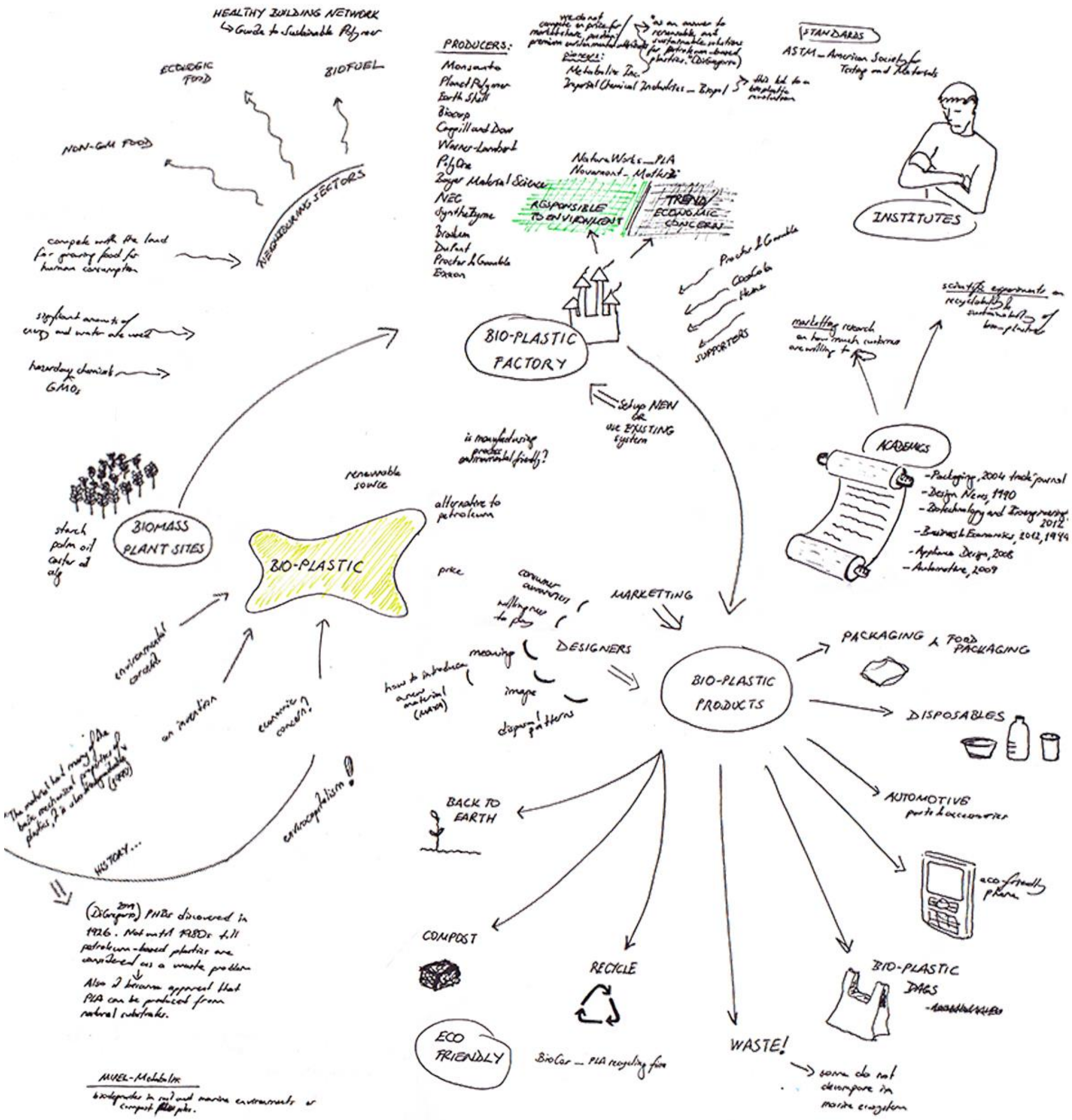
Wilkinson, J. (2011). From Fair Trade to responsible soy: Social movements and the qualification of agrofood markets. *Environment and Planning A, 43*, 2012-2026.

Woolgar, S., and Lezaun, J. (2013). The wrong bin bag: A turn to ontology in science and technology studies? *Social Studies of Science, 43*(3), 321-340.

Woolgar, S., and Lezaun, J. (2015). Missing the (question) mark? What is a turn to ontology? *Social Studies of Science, 45*(3), 462-467.

Yates, J.S., and Gutberlet, J. (2011). Reclaiming and recirculating urban natures: Integrated organic waste management in Diadema, Brazil. *Environment and Planning A, 43*(9), 2109-2124.

APPENDIX A


HEALTHY BUILDING NETWORK
ECOLOGIC FOOD
BIOFUEL
NON-GM FOOD
PRODUCERS:
Monsanto
Planet Polymer
Earth Shell
Cargill and Dow
NEC
DuPont
Procter & Gamble
Exxon
NatureWorks PLA
RESPONSIBLE TO ENVIRONMENT
TREND
ECONOMIC CONCERN
STANDARDS
INSTITUTES
BIO-PLASTIC FACTORY
SUPPORTERS
ACADEMICS
BIOMASS PLANT SITES
BIO-PLASTIC
renewable source
alternative to petroleum
price
MARKETTING
DESIGNERS
BIO-PLASTIC PRODUCTS
PACKAGING & FOOD PACKAGING
DISPOSABLES
AUTOMOTIVE
BACK TO EARTH
HISTORY...
COMPOST
RECYCLE
WASTE!
BIO-PLASTIC BAGS
ECO FRIENDLY