Received: 14 October 2023 | Revised: 30 August 2024 | Accepted: 23 September 2024

DOI: 10.1002/bse.3997

RESEARCH ARTICLE

Business Strategy and the Environment

WILEY

Competing narratives inhibit a circular economy for bio-based plastic packaging: Insights from a social innovation lab study in Brazil, Canada, Poland and the UK

Belinda Li[1] | Jordon Lazell[2] | Macarena Beltran[3] | Grażyna Kędzia[4] | Lais Roncalho Lima[5] | Tammara Soma[1] | Sandra Andrea Cruz[5] | Rafaela Francisconi Gutierrez[6] | Jolanta Turek[7] | Marta Raźniewska[4] | Aneta Pluta-Zaremba[7] | Benny Tjahjono[3]

[1]School of Resource and Environmental Management, Simon Fraser University, Burnaby, Canada

[2]Essex Business School, University of Essex, Colchester, UK

[3]Centre for Business in Society (CBiS), Coventry University, Coventry, UK

[4]Department of Logistics, Faculty of Management, University of Lodz, Poland

[5]Chemistry Department, Federal University of São Carlos (UFSCAR), São Carlos, Brazil

[6]Department of Ecology and Evolutionary Biology, U of T Trash Team, University of Toronto, Toronto, Canada

[7]Collegium of Business Administration, SGH Warsaw School of Economics, Warsaw, Poland

Correspondence
Belinda Li, School of Resource and Environmental Management, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6, Canada.
Email: belinda_li@sfu.ca

Funding information
This work was supported by the Trans-Atlantic Platform through the São Paulo Research Foundation (FAPESP) grant numbers 2020/04239-1 and 2019/02576-3, Trans-Atlantic Platform Social Innovation, Social Sciences and Humanities Research Council (SSHRC) grant number 20022019-0003, National Centre for Research and Development (NCBR) grant number T-AP SI/SIMBIO/1/2020, and UK Economic and Social Research Council (ESRC) grant number ES/T015195/1.

Abstract

Businesses are turning to bio-based, compostable plastic packaging as a circular economy solution to global plastic pollution. However, there is a lack of proper waste management systems for collection and processing. Through an international research initiative, a social innovation lab was undertaken in Brazil, Canada, Poland and the United Kingdom to understand and address key barriers in closing the bio-based plastic packaging loop. Based upon a qualitative data set of 100 stakeholder interviews and three phases of workshop activities in each country, a grounded model was generated to illustrate how competing views and actions are inhibiting a circular system for bio-based plastic packaging. Key issues were the lack of end-of-life processing infrastructure, contamination in processing facilities and absent or ineffective regulation. A systemic approach that includes shared responsibility for infrastructure, simplified packaging design and materials and equitable regulation to reduce susceptibility to greenwashing can improve collaboration to meet circular goals.

Abbreviations: AD, anaerobic digestion; ADBA, Anaerobic Digestion and Bioresources Association; B2B, business-to-business; BBIA, Bio-based and Biodegradable Industries Association; BPI, Biodegradable Products Institute; COVID-19, coronavirus disease 2019; ECBPI, European Circular Bioeconomy Policy Initiative; EPR, extended producer responsibility; EU, European Union; NPSW, National Policy on Solid Waste; OPRL, on-pack recycling label; REA, Association for Renewable Energy and Clean Technology; SIMBIO, Social Innovation Management for Bioplastics; STM, American Society for Testing and Materials; UCL, University College London; UK, United Kingdom; WRAP, Waste and Resources Action Programme.

KEYWORDS
bio-based plastic, circular economy, compostable plastic, packaging, social innovation, waste management

1 | INTRODUCTION

Interest in the circular economy has grown rapidly in recent years (Barreiro-Gen & Lozano, 2020; Suchek et al., 2021). This interest has spurred new business models and innovations such as using waste as a resource (Moggi & Dameri, 2021; Nogueira et al., 2023; Puntillo et al., 2021) and developing more sustainable products (Pinkse & Bohnsack, 2021), such as producing plastic materials from bio-based sources (Gurunathan et al., 2015; Kochańska et al., 2021). 'Bio' here refers to biologically derived materials and is part of a wider bioeconomy proposed as a more sustainable replacement to using environmentally damaging materials such as fossil fuels (Hinderer & Kuckertz, 2022). Bioplastic packaging is one application of many within the bioeconomy, and is commonly perceived by businesses, institutions and consumers as a sustainable packaging option (Dilkes-Hoffman et al., 2019; Meeks et al., 2015).

As a broad term, bioplastics encompasses both bio-based plastics, which are made wholly or partly from biomass, and biodegradable plastics, which break down into components such as biomass, water, carbon dioxide and methane according to the specifications in a standard or test method (Atiwesh et al., 2021; Lackner et al., 2023; Lambert & Wagner, 2017). While scholars in this field have been advocating for clear definitions that all stakeholders should adopt to overcome confusion in the literature, there are still no standard definitions used in the sector. A confusing scenario has arisen whereby some bio-based plastics can be non-biodegradable, while some other non-bio-based plastics are biodegradable. This lack of clarity comes from the broadly defined nature of the term biodegradable, as this does not automatically mean that degradation will happen in any environment (Atiwesh et al., 2021; Prieto, 2016). Instead, degradation may require certain conditions. For example, bio-based compostable plastics (referred to as compostable plastics for brevity) typically can only degrade in industrial composting facilities if the right conditions are met (Lackner et al., 2023; Lambert & Wagner, 2017). In this paper, we focus on bioplastics that are bio-based. Table 1 gives further clarification of the definitions of plastics used in this paper based on review articles in this field. The term "conventional plastic" was added to this paper to refer to plastics that are not bioplastics, in other words, derived from fossil fuels.

Despite the environmental sustainability claims associated with bio-based plastics, there is still a lack of consensus on their environmental impacts. Studies on the environmental impacts of bio-based plastics are generally technologically focused, such as through life cycle assessments. Spierling et al. (2018) as well as Walker and Rothman (2020) warn of difficulties in the application of such assessments to bioplastic materials given the unestablished nature of their use and development. Furthermore, results are highly variable and depend on factors such as the raw material source, how residues and side streams are treated, transport distances and end-of-life management (Bishop et al., 2022; Hottle et al., 2013; Van Roijen & Miller, 2022). End-of-life management is often not included in life cycle assessments and is currently a blind spot in sustainability assessments of bio-based plastics (Gerassimidou et al., 2021). When end-of-life management is taken into consideration in life cycle assessments, then greenhouse gas emissions could increase due to the degradation of bio-based plastics in landfills (Hottle et al., 2013; Van Roijen & Miller, 2022). While a global figure specific to bio-based plastics is not available, landfilling is a common route of disposal according to one study in the United States (Meeks et al., 2015).

In the food sector, which uses a large amount of single-use packaging, bio-based plastics are seen as a substitute that supports the circular economy (Tan et al., 2021; Tardy et al., 2022). Global acceptance of bioplastic packaging as a replacement for conventional plastic packaging is high (Kochanska et al., 2022). Studies have found that consumers are willing to pay a premium for food products in bio-based plastic packaging (Findrik & Meixner, 2023; Skouloudis et al., 2023), although the premium may be very low (Kochanska et al., 2022). There are, however, social challenges associated with the use of bio-

TABLE 1 Plastic definitions.

Term	Definition
Bio-based plastic	Plastic that contains organic carbon from a renewable origin such as "agricultural, plant, animal, fungi, microorganisms, marine, or forestry materials living in a natural environment in equilibrium with the atmosphere" (ASTM, 2016, as cited in Lambert & Wagner, 2017, p. 6857). This also includes "partially bio-based (or hybrid) plastics" that are made from a mix of bio-based materials and fossil fuels (Atiwesh et al., 2021, p. 2).
Biodegradable plastic	Plastic that "can be broken down into monomeric or polymeric components, including biomass, water and carbon dioxide or methane, via microorganisms" (Atiwesh et al., 2021, p. 2).
Compostable plastic	"Plastic that undergoes biological degradation during composting to yield carbon dioxide, water, inorganic compounds, and biomass at a rate consistent with other known compostable materials and leaves no visually distinguishable or toxic residues" (ASTM, 2012, as cited in Lambert & Wagner, 2017, p. 6857). While this can include industrial or home composting, only industrial composting is considered in this paper to align with common testing standards for compostability.
Conventional plastic	Plastic that is derived from fossil fuels.

based plastic packaging. COVID-19 has exacerbated the reliance on single-use plastic packaging for sanitary reasons and bio-based packaging is seen as a viable replacement, yet its social sustainability is questioned because the demand for raw materials may compete with food resources (Brizga et al., 2020; Kochanska et al., 2022).

With regards to the development of bio-based plastics as a circular economy, consumer-focused studies have found that with such a wide range of products on the market, users do not know or are confused about what different types of plastics are and their disposal routes (Dilkes-Hoffman et al., 2019). Studies have also shown how bioplastic waste management infrastructure has not been designed appropriately due to the lack of processing facilities or problems that these products cause within facilities (Kakadellis et al., 2021; Lambert & Wagner, 2017; Meeks et al., 2015). Multiple sectors like packaging, food and waste management, are all important actors in the bio-based plastic packaging supply chain (or product life cycle, in circular economy terms), yet have differing business priorities and operations (Gerassimidou et al., 2021). End-of-life management challenges for bio-based plastic packaging, therefore, can be considered a 'wicked' problem as it is seemingly impossible to solve due to the numerous interdependent factors that simultaneously impact circular economy solutions (Hopkinson et al., 2018; Rittel & Webber, 1973), leading many scholars to question its premise (Corvellec et al., 2022). The situation echoes studies that have explored the tensions businesses contend with in pursuing circular economy goals (Daddi et al., 2019), whereby firm competitiveness and product quality have been noted as being negatively affected (De Angelis, 2021). Implementing a circular economy has frequently been described as 'paradoxical' as efforts to make social and environmental improvements compete with the complex reality of business practices and different system levels that support such arrangements (Dagilienė & Varaniūtė, 2023; Van Der Byl & Slawinski, 2015). Exploring these competing tensions is an emerging field of work with a significant gap in considering the circular economy challenges faced within the bio-based material sector.

Whilst collaborative, multi-stakeholder initiatives are well-suited to working on wicked problems (Dentoni & Bitzer, 2015), such solution development approaches have not been widely used in the field of bioplastics with the exception of this study and the Aachen bioplastic living lab. Bringing together 15 research groups across social, natural and engineering sciences as well as members of the public and wider stakeholders, the Aachen bioplastic living lab is still ongoing but initial findings display how such initiatives can act as a catalyst to overcome persistent challenges in synchronising multi-actor change (Backhaus et al., 2023).

To address the complex challenges of bio-based plastic packaging throughout its entire supply chain from production to end-of-life management, a joint project was carried out in Brazil, Canada, Poland and the United Kingdom (UK) as part of an international social innovation research collaboration initiative. While these countries represent different states of bio-based plastic packaging market development, infrastructural development and policy, there was a common theme throughout: Participants raised concerns and frustrations about how compostable plastic packaging is not being composted but is instead disposed of as garbage. This was seen as a key gap in closing the product cycle for compostable plastic packaging to be a truly circular innovation. While the objectives of the overall project had a wider scope, for this paper, the research questions are focused on the end-of-life management gap:

1. What is preventing bio-based plastic packaging from fully integrating into the circular economy?
2. What are the potential solutions to these challenges and what factors will influence their adoption?

A social innovation lab process (Domanski et al., 2020; McGann et al., 2018; Nesti, 2018; Westley & Laban, 2015) was used to strategically bring participants, businesses active in these supply chains, together to develop a common understanding of a problem and collaborate innovative solutions through iterations of information collection, analysis, creative engagement and prototype development. It provided a whole systems approach with the intent of exploring solutions that result in a profound and permanent shift in the social system. This study is unique in eliciting the viewpoints of diverse participants through dialogue and co-creation from social innovation lab workshops in four distinct regions around the world (Brazil, Canada, Poland and the UK).

In the study of sustainability transitions, narratives are "a story ascribing meaning to social or physical phenomena by connecting a sequence of events and actions in a plot" and can "fundamentally enable or constrain our thought spaces and practical options for the future" (Leipold, Weldner, & Hohl, 2021, p. 2). Narratives can also shape the interpretation of problems and prioritisation of solutions. In the interviews and during the interactions between participants working in different areas of the supply chain in the social innovation lab workshops, it became clear that there were competing narratives on the end-of-life management of bio-based plastic packaging. Further exploration of these tensions through facilitated activities during the labs generated rich insights that would not have been uncovered through traditional research methods, such as surveys, interviews and focus groups. Through analysing the competing narratives that emerged from this research, this paper offers new perspectives on how current solutions are falling short of achieving circularity and systems-oriented interventions that could be more effective in closing the loop for bio-based plastic packaging.

2 | REGIONAL CONTEXT

Given the large geographic spread of this research, there are different social, cultural and political contexts to consider. Table 2 provides an overview of the state of the bio-based plastic packaging sector in each country based on a review of the literature. The availability of literature specific to each country varied greatly and, in some cases, was very sparse. Therefore, the information presented in Table 2 may not be directly comparable between each country but instead serves as background to contextualise the findings in this study.

TABLE 2 Local context by country.

Context	Brazil	Canada	Poland	United Kingdom
Market conditions	• Small niche due to major barriers to expanding the market due to high cost of investment for companies and lack of end-of-life management options (Lima et al., 2021).	• Emerging market for compostable plastics (including packaging) forecasted to grow an average 3.61% (Compound Annual Growth Rate) per year from 2024 to 2028 (TechSci Research LLC, 2023).	• Emerging market with the share of plastic packaging made of biodegradable materials forecasted to reach 10% by 2025 (Polish Chamber of Packaging, 2019).	• Emerging niche oriented towards the hospitality and catering sector (Circular Bio-based Europe, 2022).
Public perception	• There is evidence that the public has shown an interest in purchasing bio-based plastics (La Fuente et al., 2022).	• Consumers willing to pay more for items in biodegradable packaging (T. R. Walker et al., 2021).	• 75% of Polish consumers say sustainability is an important aspect in their lives and in their purchasing decisions. Two-thirds of those surveyed express a willingness to pay more for more environmentally friendly products. A 20% increase in the price of such products results in a drop in demand of up to 62%. 61% say they are reducing single-use packaging (Jordan-Kulczyk et al., 2021).	• Hope and optimism for environmental benefits, but also scepticism over environmental claims and how packaging waste is processed and disposed (Allison et al., 2021). • Negative reactions around product quality (Simms et al., 2020).
Waste management infrastructure	• Limited infrastructure for composting due to high development costs (Beltrame et al., 2019). • Waste picker cooperatives are a key service in municipalities for collecting and sorting recyclable materials (Lima et al., 2022).	• Source-separated organic waste collection and composting or anaerobic digestion facilities in most large cities, but most facilities do not accept compostable plastics (Springle et al., 2022).	• Waste management infrastructure is still dominated by landfilling, but composting has been developing more rapidly in recent years (Główny Urząd Statystyczny, 2022; Smol et al., 2019). • Due to increasing demand, the country will need 11 to 17 more composting facilities by 2034 (Szincel, 2021). • There is no formal code for bio-based plastic packaging waste (Portal Komunalny, 2022), so it is not compatible with composting plants.	• Local authorities mandated as of 2023 to collect and separate food waste (Department for Environment, Food, & Rural Affairs, 2023). • Significant composting and anaerobic infrastructure to process food waste material, but end-of-life processing for compostable plastics is limited (Beltran et al., 2021; Kakadellis et al., 2021).
Standards or certifications	• Brazil has its own standard for biopolymers (NBR 15448/1:2008) and compostable plastics (NBR 15448/2:2008) (Sarantópoulos & Rego, 2020).	• Two organisations provide certification compostable plastics: (1) Bureau de Normalisation du Québec (BNQ) certifies to CAN/BNQ 0017–088, based on ISO 17088, and (2) Biodegradable Products Institute (BPI) certifies to ASTM D6400 and D6868 (Environment and Climate Change Canada, 2022).	• Companies may use TÜV AUSTRIA (Belgium) or DIN CERTO (Germany) certifications based on European standard EN 13432 on packaging composting and biodegradation (European Committee for Standardization, 2000), harmonised with packaging and packaging waste directive 94/62/WE (European Parliament and Council, 1994).	• UK Plastics Pact (WRAP, 2024). • The Bio-based and Biodegradable Industry association "exists to champion the industrial bioeconomy to accelerate the development and adoption of bio-based and biodegradable materials and products through advocacy, collaboration, and education" (BBIA, 2024).
Regulations	• Plastics labelled as compostable must meet NBR 15448/1:2008 and NBR 15448/2:2008 standards (Sarantópoulos & Rego, 2020). • Multiple states and municipalities have laws that prohibit single-use items (Lima et al., 2021).	• Single-use Plastics Prohibition Regulations includes ban on compostable and biodegradable plastic bags and foodservice ware. (Environment and Climate Change Canada, 2023a), but was overturned by the federal court (Major, 2023). • Federal regulatory framework for labelling plastics is under development and includes requirements for compostable labels to only be	• Proposal for a directive on substantiation and communication of explicit environmental claims, known as the green claims directive. • Single-use plastic reduction: Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment.	• Lack of comprehensive regulatory framework for bioplastics, focusing instead on continuous monitoring.

TABLE 2 (Continued)

Context	Brazil	Canada	Poland	United Kingdom
		applied to certified products and prohibits the use of the terms biodegradable or degradable (Environment and Climate Change Canada, 2022).	• Directive (EU) 2019/904 of the European Parliament and of the council on the reduction of the environmental impact of certain plastic products. • Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste as regards Articles 8 and 8a, which relate to extended producer responsibility (EPR).	
Targets and strategic plans	• No targets or strategic plans.	• Canada Plastics Pact between businesses, government, and non-governmental organisations has targets of 100% of plastic packaging being designed to be reusable, recyclable or compostable by 2025 and at least 50% of plastic packaging is effectively recycled or composted by 2025 (Canada Plastics Pact, 2021).	• 2030 National Waste Management Plan aims to develop infrastructure for both aerobic and anaerobic organic recycling, which also accepts biodegradable packaging waste (Styś et al., 2018).	• Plastic pact between many key industry organisations across the value chain is targeting all packaging to be reusable, recyclable, or compostable by 2025 - The UK Plastic Pact (WRAP, 2024).

In Canada, Poland and the UK, bio-based plastic packaging is an emerging market that is projected to grow, especially in the food sector. For these three countries, while composting and anaerobic digestion facilities exist, many are not prepared to process compostable plastics. In Brazil, the market remains a small niche due to the high investment cost for product development and the lack of composting infrastructure. Public perception of bio-based plastic packaging is generally positive across all four countries, but there is some scepticism around environmental claims and product quality. Standards and/or certifications for industrially compostable plastics exist in all four countries, but only Brazil has a regulation that mandates such standards to be met for products to be labelled as compostable. In Canada and Poland, regulatory frameworks to govern the labelling of environment claims on products (including compostability) are under development. Broader regulations restricting the use of single-use plastic products such as shopping bags and straws are in place in Canada and Poland (as part of the European Union), which include bio-based plastics. Strategic plans and targets include plastic pacts by industry for plastic packaging to be reusable, recyclable or compostable by 2025 (Canada and the UK) and infrastructure development for aerobic and anaerobic recycling (Poland).

3 | MATERIALS AND METHODS

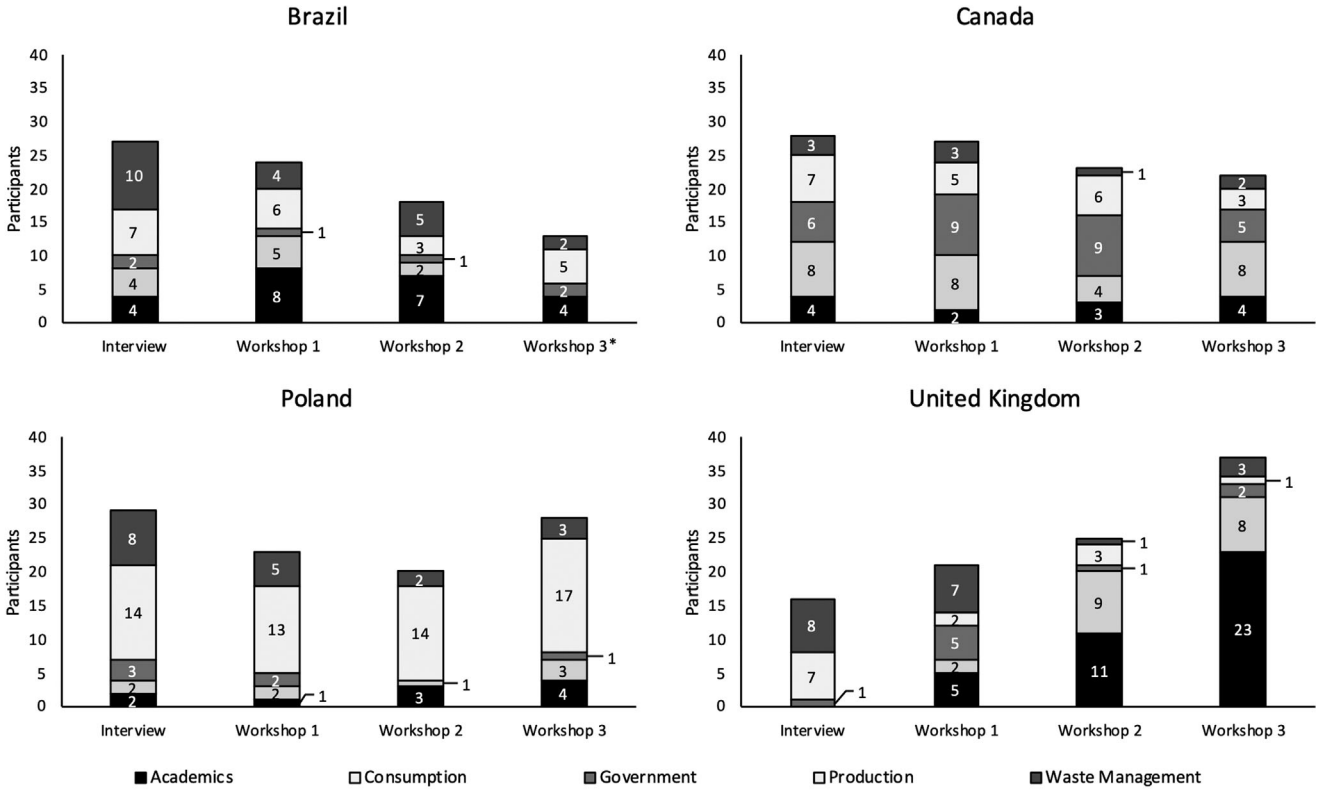
Each country's research team followed a similar social innovation lab process that included four phases based on Westley and Laban (2015) (1) defining the challenge, (2) understanding the system, (3) exploring solutions and (4) prototyping solutions. Phase 1 consisted of key informant interviews to define the challenge of bio-based plastic packaging and establish a convening question for the social innovation lab workshops. Phases 2 to 4 consisted of a series of three social innovation lab workshops that roughly followed the method from Westley and Laban (2015). This process was customised for each country based on the local context, participants and restrictions due to the COVID-19 pandemic. Research ethics approval was granted by each of the universities in the consortium for the research activities conducted in each country. Table 3 gives an overview of the methods employed throughout the project. The description of these methods is offered within the presentation of the four phases of the research project as this best describes how the project took place.

3.1 | Recruitment

Participants were recruited purposively based on their knowledge of and experience with bio-based plastic packaging. A good coverage was achieved of stakeholders operating across the bioplastic supply chain. Potential participants were first identified through existing contacts who are connected to bio-based plastic production, use, end-of-life management, research or governance. To improve representation from different parts of the product life cycle, additional potential participants were identified via web searches, engagement

TABLE 3 Overview of the methods employed throughout the four phases of the project.

Project phase	Methods employed
1. Defining the challenge	Literature review Semi structured interviews (mostly online)
2. Understanding the system	Social innovation lab workshop activities: • focus group discussions • collaborative group activities (system role identification) • mapping of barriers and opportunities • identification of leverage points
3. Exploring solutions	Social innovation lab workshop activities: • solution identification • solution visualisation • ideation of business models
4. Prototyping solutions	Social innovation lab workshop activities: • presentation and narrowing down of applicable solutions • evaluation of the feasibility, practically and potential impact of proposed solutions • gamification of decision making around the implementation of potentials and their configuration



* Workshop 3 in Brazil was open to the public. The number of participants representing consumers was not tabulated.

FIGURE 1 Participants by country and sector.

with industry associations and referrals from existing contacts. A comprehensive list of potential participants was created for each country. Invitations to participate in the different phases of the project were sent to relevant potential participants from the lists based on their knowledge domain. See Figure 1 for an overview of the participant types by country and project phase.

3.2 | Phase 1: defining the challenge

A total of 100 participants took part in semi-structured interviews between February 2020 and June 2021. Questions were open-ended and covered topics such as perceptions of bio-based plastic packaging, current production, use and end-of-life management processes,

drivers, enablers and inhibitors to the market, and identification of key stakeholders in the product life cycle. Almost all interviews were conducted via web conferencing or telephone. A few interviews in February 2020 were conducted in-person before COVID-19 became a global pandemic. The interview duration ranged from 30 to 120 minutes, with most interviews taking approximately 45 to 60 minutes. Interviews were recorded via a digital voice recorder or through web conferencing software.

3.3 | Phase 2: understanding the system

The objective of this phase was to develop a common understanding of the key challenges and barriers in the production, use and end-of-life management of bio-based plastic packaging. Lab workshops (Lab 1) were held between October 2020 and July 2021 and engaged a total of 95 participants. Examples of workshop activities included focus group discussions, building group timelines, reflecting on participants' roles in the system, identifying barriers and opportunities, mapping barriers and opportunities using different techniques (e.g., systems mapping, cause-and-effect diagrams), and identifying leverage points. Workshops were convened online using Zoom or Microsoft Teams. See Appendix A for the workshop agendas by country.

3.4 | Phase 3: exploring solutions

This phase aimed to evaluate current innovations in bio-based plastic packaging, their successes, failures and shortcomings. The workshops were designed to expand thinking on possible social innovation solutions and identify solutions for rapid prototyping. Lab workshops (Lab 2) were held between February 2021 and January 2022 and engaged a total of 86 participants. Examples of workshop activities included visualising solutions with bricolage, mapping out solutions on a business model canvas (Miro, n.d.), clustering and prioritising solutions with online tools and focus group discussions. Workshops were convened online using Zoom, Microsoft Teams or Gather. Town. See Appendix A for the workshop agendas by country.

3.5 | Phase 4: prototyping solutions

The original objective of this phase was to test and prototype solutions within the social innovation lab container to evaluate their feasibility, practicality and potential impacts. Based on the findings of the previous phases, the approach for this phase was more flexible with the workshop content appropriated to the relevant context of each country. In Brazil and the United Kingdom, workshops were convened in a hybrid format with some participants attending in-person and others online. In Canada and Poland, workshops were convened completely online using either Zoom or Microsoft Teams.

In Brazil, presentations were made by 13 stakeholders to explain their products already developed or under development to be pitched as potential solutions. The event was presented in four sessions with the following themes: Legislation, Market, Waste Management and Research and Development. After each block of presentations, interactive debates were held between the team, stakeholders including waste pickers and general consumers.

In Canada, a gamification approach (Li et al., 2023) was used to prototype two solutions that dominated discussions in the previous phase: standardised plastic labels and single-use plastic bans. For the first game, participants designed labels for different types of plastics (including compostable plastics) in groups and then tested how well these plastics were sorted by other groups via an online game. For the second game, participants designed a retail system without single-use plastics in groups for a specific product which was then evaluated by another group for its feasibility.

In Poland, the three top solutions identified by stakeholders as those with the greatest potential to stimulate the development of the compostable packaging market in Poland underwent rapid prototyping and testing. The solutions were: a national strategy for the development of the compostable packaging market, an industry organisation and a digital multi-sided business-to-business platform. Stakeholders worked in three discussion panels. Each panel was devoted to a multidimensional discussion on the design of a given solution and the possibility of its implementation. Stakeholders filled in a business model canvas (Miro, n.d.) in terms of five to seven key elements describing the solution, including strategic goals, tangible and intangible resources to be created and operated, or types of risk for the success of the implementation.

In the UK, experts presented each of the six solution areas (Tjahjono et al., 2022). Participants then discussed each cluster solution in break-out groups in terms of its transformative potential. The break-out discussions posed three evaluative factors: feasibility, practicality and configurations for proposed innovations. Participants then played a scenario game to prototype feasible systemic solutions for specific bio-based biodegradable plastic products (Tjahjono et al., 2022).

Lab workshops were held between April 2021 and June 2022 (Lab 3) and engaged a total of 89 participants. See Appendix A for the workshop agendas by country.

3.6 | Analysis

Audio recordings of interviews were transcribed manually or using the Otter.ai transcription tool. Each country's research team coded the transcripts according to their own codebook. Observations and outputs (e.g., notes taken by research assistants, Miro whiteboards, group diagrams, game results) from workshops were summarised as internal notes or reports that were shared with workshop participants. Key findings from the workshops by country and activity are included with the agendas in Appendix A. The combination of transcripts, internal notes, workshop findings and reports served as the data for analysis.

Inductive and deductive approaches were employed iteratively to code the data. Gioia et al.'s (2013) method of qualitative data analysis provided a basis for the collaborative process through which the themes were derived from the data. Figure 2 gives an overview of

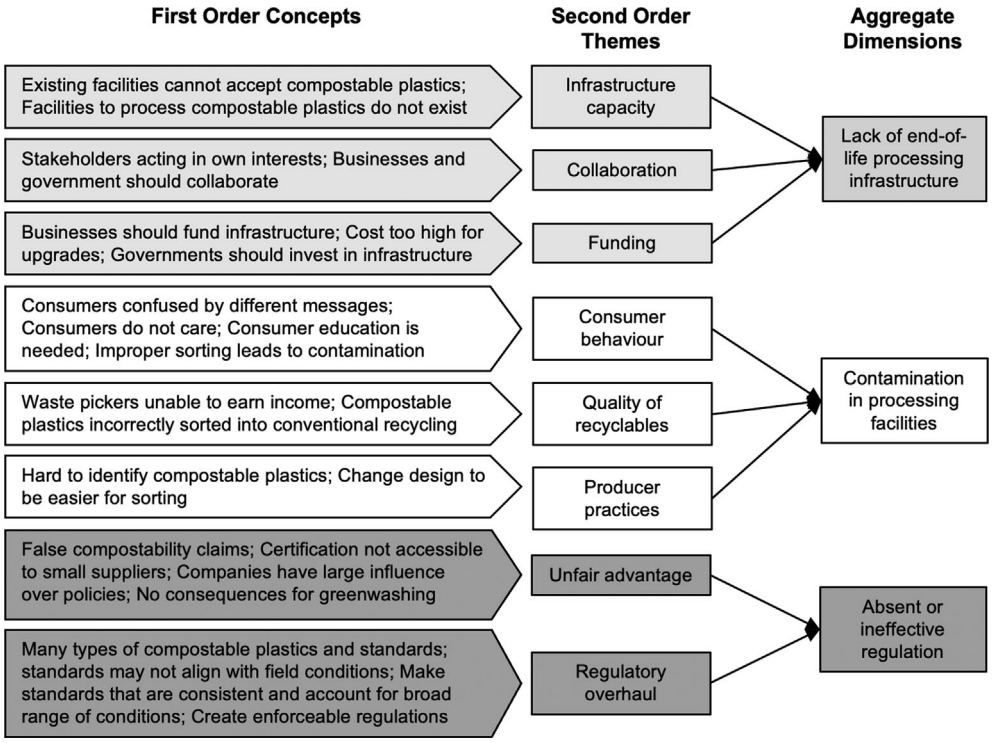


FIGURE 2 Coding themes.

the first-order concepts, second-order themes and aggregate dimensions.

The consortium first met to identify general discussion topics that generated polarised opinions during participants' discussions. The consortium selected topics that were common between the countries: communication about bio-based plastic packaging, impacts on waste management systems and equity issues. The research team in each country then reviewed their data to identify excerpts that were relevant to each topic. Excerpts from Brazil and Poland were translated into English by a member of the country's research team. The excerpts were compiled into one data set and inductively coded by one of the researchers on the Canadian team into first-order concepts.

The first-order concepts were then organised into second-order themes. Three aggregate dimensions were derived from the second-order themes and represent broader narratives which frame the problem of why bio-based plastic packaging is not being properly managed at end-of-life and solutions to overcome it: (1) lack of end-of-life processing infrastructure, (2) contamination in processing facilities and (3) absent or ineffective regulation. The coding was reviewed by at least one other researcher from each country for accuracy and revised as needed. Each country team contributed additional examples of first-order concepts that were relevant to the second-order themes from their findings. A grounded model was then generated from the aggregate dimensions and how they relate to the linear and circular economy.

3.7 | Limitations

While this study engaged diverse stakeholders that represented a variety of professions, sectors and regions, it may not be representative of all the viewpoints from different stakeholder groups in the bioplastics sector. To achieve deeper and more meaningful conversations and interactions, a key strength of this research project, the number of participants had to be limited. This limitation was mediated through additional literature review to gain other perspectives and facilitating activities that encouraged participants to think about problems and solutions in multiple ways. Since most of this research was conducted during the COVID-19 pandemic, most interviews and workshops took place online. This was a barrier to participation for some stakeholder groups, particularly waste pickers (also known as binners). In Brazil, where waste pickers are a key stakeholder group, support was provided for virtual participation and a hybrid event was held to improve accessibility.

4 | FINDINGS

This section is organised by the aggregate dimensions and their associated second-order themes.

4.1 | Lack of end-of-life processing infrastructure

4.1.1 | Infrastructure capacity

There was consensus from all four countries that end-of-life processing infrastructure for compostable plastic packaging is lacking. In places with little to no processing infrastructure such as Brazil, rural regions of Canada and some parts of Poland, compostable plastic packaging must be disposed of as garbage, as explained by this interview participant:

> *"It is necessary to send [compostable plastics] to composting plants, which are practically non-existent in Brazil. This material does not have a destination, it is not recycled like plastic, it is not recycled like other materials, it can only be recycled as a part of the industry itself."* -
> Interview 1 (Production), Brazil

In urban regions of Canada, the UK and most of Poland, processing facilities for organic waste are already established for green waste like garden waste and food waste. However, most facilities do not accept, or only accept limited amounts of compostable plastic packaging. There are a range of compostable plastic packaging products with different properties and certification standards. For example, compostable plastics may degrade well in industrial composting facilities (e.g., windrows, in-vessel), but anaerobic digesters are not well suited to compostable plastic packaging, as explained by this lab participant:

> *"You cannot just put a load of plastics into a digester and an autoclave to make it digest. It does not work … it nearly broke the machine … [with] the sticky residue nature of these plastics, they basically got stuck to one side of the machine."* -
> Lab 2, Participant 52 (Waste Management), U K

As the typical operating conditions or the technology used by the processing facility may not be suitable for handling compostable plastics, even if they are certified, upgrades are necessary so the materials can properly degrade and not cause operational challenges.

4.1.2 | Funding and collaboration

High capital investments are needed for both the development of new facilities and retrofitting of existing facilities. In the UK, during the second and third Lab, the need for capital investment for infrastructure was identified, but divergent opinions emerged about who should pay for such investments. If government funds are to be used to facilitate the sector's development, there was a debate on which activities should be the focus, and which stakeholder funds should be aimed towards. Similarly, in Poland during Lab 1, participants identified a lack of sufficient investments for composting infrastructure due to low public interest in using composting infrastructure, limited investment by local governments in the circular economy and lack of interest of public administration bodies for the contribution of biowaste to the economy (Raźniewska, 2022).

For existing facilities, processing technology can be adapted to be more suitable for processing compostable plastic packaging (Kakadellis et al., 2021), but are subject to a lock-in effect (Grin et al., 2010), as identified during a system mapping exercise in Canada (Lab 1). Due to the large amount of physical infrastructure involved, the payback periods for capital investments can last decades. Facility owners (e.g., governments, businesses) therefore are committed to the use of a certain technology until the end of the payback period. Processing facilities built before compostable plastic packaging became more popular are therefore locked-in to their current technology unless major capital investment can be obtained.

To overcome the funding problem for upgrading or building new facilities, one private sector funding mechanism discussed in Lab 2 in Canada was Extended Producer Responsibility (EPR) for compostable plastic packaging (Springle et al., 2022). Under this mechanism, packaging producers fund end-of-life management infrastructure. Supporting reverse logistics for bio-based plastic packaging in a similar manner to EPR was also discussed in Labs 1 and 2 in Brazil, although the focus was on regulation (see 4.3). The challenge in Canada is that EPR is established on a provincial or territorial basis, not across the entire country. Like the UK (Kakadellis et al., 2021), compostable plastic packaging is still a very small fraction of the waste stream. Even though compostable plastics are technically included in EPR for residential packaging in British Columbia and Ontario, the stewardship agencies in both provinces are not targeting the collection of these materials because their quantities are so low (Government of Ontario, 2023; Recycle BC, 2019). Therefore, funding from an EPR program in a single province or territory (or a few) might not be adequate to make any improvements for end-of-life management. While the responsibility for funding end-of-life infrastructure remains an ongoing debate, it is likely that contributions need to be made from both businesses and government.

4.2 | Contamination in processing facilities

4.2.1 | Consumer behaviour

The introduction of compostable plastic packaging into biowaste has led to contamination in processing facilities. Even if facilities are built or upgraded to be able to handle compostable plastics, the contamination problem will persist without some type of intervention. Compostable plastic packaging looks and feels like non-compostable plastic packaging, so they cannot be differentiated from each other (Findrik & Meixner, 2023). Non-compostable plastic packaging is then mistakenly sorted as organic waste by consumers (Law & Narayan, 2021). Processing facilities carry the financial burden of paying to dispose of items that are unacceptable in their systems (Kakadellis et al., 2021). The resultant consequence of inaccurate sorting is high rates of rejections by processing facilities because they are too contaminated (Meeks et al., 2015).

Different labelling schemes currently exist such as the Möbius Loop for recycling or the Seedling Logo for composting (Tkaczyk et al., 2014). While these labels are widely used on plastic packaging (where applicable), they do not appear to be effective in guiding consumers to sort plastic packaging into the correct waste stream for processing due to confusion and unfamiliarity (Buelow et al., 2010). Even though the Möbius Loop is widely recognised for recycling, there are multiple symbols used to depict that plastic is compostable so it may not be well-known to consumers, as this interview participant observed:

> *"It turns out that this (the Seedling Logo) is an under-recognised symbol, especially when you enter an eco shop where everything is BIO and this symbol 'disappears' in a certain way."* -
>
> Interview 14 (sector), Poland

Sorting confusion was evident in the results from the *Can You Sort It?* game (see 3.5) played during Lab 3 in Canada (Springle et al., 2022). Even though participants were mostly experts and professionals who were knowledgeable in this field, only 65% of the plastic packaging items were correctly sorted. This level of sorting accuracy is like other studies that observed waste sorting behaviours more broadly (Luo et al., 2019; Wu et al., 2018). Consumer confusion over how to sort bio-based plastic packaging was also highlighted at Lab 3 in the UK in a video shared by an industry association.

4.2.2 | Quality of recyclables

The lack of differentiation between compostable and non-compostable plastics does not just affect processing facilities for biowaste, it also affects conventional recycling. This interview participant describes how plastic recycling facilities are also facing a contamination problem:

> *"Consumers mistakenly throw bioplastic [referring to compostable plastic] into conventional plastic waste, then in the sorting plant, workers are unable to recognize the bioplastic and it becomes a contaminant in the stream of conventional plastic waste."* -
>
> Interview 3 (Producer), Poland

In Brazil, where it is more common for waste pickers to collect plastic packaging and sort it into different categories to sell to recycling facilities, the contamination of conventional plastic packaging waste with compostable plastic packaging waste impacts the quality of recyclables and, consequently, their market price (Correa et al., 2022). This can be a threat to their livelihoods:

> *"With these new biodegradable plastic technologies, we (waste pickers) will not be able to add income, as buyers and large industries do not absorb this material, there is no return to the cycle."* -
>
> Interview 15 (Waste Management), Brazil

Instead of relying solely on labels for sorting plastic packaging, the design of plastic packaging can be changed so that it is easier to sort. When discussing ways that the impact on waste pickers can be reduced during Lab 1 in Brazil, industry representatives proposed simpler packaging that can be recycled and/or composted.

4.2.3 | Producer practices

Rather than taking a downstream approach that focuses mostly on costly waste management infrastructure, an upstream approach that controls the materials going into processing facilities could enable the loop to be closed for compostable plastics with lower capital investment and increase the willingness of waste processors to accept these materials. To do this, there needs to be an easy way to identify if plastic packaging is compostable or not to prevent contamination at processing facilities, as described by this interview participant:

> *"I think there needs to be clear identification because a lot of the greenwashing that's going on, there's different companies like [name of brand] has a bag that's green … light green, almost looks compostable, so people think that that bag is compostable, they use it to throw their organic waste … you know I've had loads where there's hundreds of those green bags…"* -
>
> Interview 14 (Waste Management), Canada

Across all four countries, a common solution proposed by participants is for producers of plastic packaging to use standardised labelling so bio-based compostable, bio-based non-compostable and conventional plastic packaging can be differentiated throughout the product life cycle. This can overcome current challenges in signalling which products are compostable, and thus improve adoption of compostable packaging and proper disposal (Baskoro et al., 2023).

A second approach is to change the design of the packaging itself. Collaboration in developing bio-based plastic packaging (co-innovation) mostly occurs between suppliers and consumers (Liliani et al., 2020), so the waste management sector and its associated concerns are underrepresented in the design process. Current developments in packaging design favour the use of multilayer films and material blends due to their lighter weight and better performance (Schmidt et al., 2022). Designers may not be aware of the end-of-life implications of their packaging products, such as the specific conditions needed for biodegradation (Liu et al., 2023). Deliberate efforts would therefore be needed to shift design paradigms that embrace circularity so end-of-life management becomes a part of standard specifications. Avoiding the use of multilayer or biopolymer mixtures for plastic packaging and sticking to a few single resin plastics that are guaranteed to be accepted by recycling or biowaste processing facilities will make sorting easier. However, a regulatory intervention would likely be necessary to restrict which plastics are permitted for packaging (see 4.3).

4.3 | Regulation is absent or ineffective

4.3.1 | Unfair advantage

There are multiple case studies of companies selling plastic packaging or products with compostable and biodegradable labels without

meeting certification standards (Goel et al., 2021). The lack of negative consequences for greenwashing has been a source of frustration for stakeholders who are trying to do the right thing, as explained by this interview participant:

> *"It's just a wholly broken system. At the moment there's no one enforcing any standards or specifications that would help in establishing a more robust, effective system and few people are actually investing in it. Investing in systems that would enable their disposal, such as this, the vast majority of plastics that are currently compostable even if, or called compostable, actually go to landfill where they will sit and just, well they'll just sit, and they will not decompose."* -
>
> Interview 8 (Consumption), Canada

Greenwashing was also identified as one of the key barriers to developing the compostable packaging industry in Poland (Kędzia & Turek, 2022). This interview participant commented on the inability to regulate the industry:

> *"However, we do not have the tools to legally react to such practices (producer fraudulently using biodegradability and compostability labels). All that remains is to report to the relevant authority."* -
>
> Interview 22 (Government), Poland

A common theme across the four countries was a strong desire amongst participants for regulation to prevent counterfeiting, fraud and greenwashing. While regulations were generally viewed in a positive light, one concern was on who makes the decisions. For example, in the UK, the government promotes the use of voluntary approaches, driving the industry to decide on regulatory standards and essentially self-regulate. This lab participant commented on how self-regulation can be problematic if the decision-making power becomes amalgamated into one body without oversight:

> *"I think that's an issue with self-regulation, is that you kind of put all of your decision making on one body that is like not technically privately run, I guess, but they do get a lot of their funding from the manufacturers and stuff. So, there's still a bit of an issue with oversight."* -
>
> Participant 48 (Academic), Lab 3, U K

Another concern about regulation is fairness. The differential impacts of regulation need to be considered such that they do not unfairly burden small businesses or start-ups that do not have as many resources. If regulation requires products to meet specific certification standards, then the certification process should be accessible to a broad range of companies. Otherwise, compliance could be cost-prohibitive for small businesses and start-ups, as this interview participant described:

> *"As a small supplier, we have not yet undertaken the certification process for our packaging. The costs of the certification procedure are high, amounting to approx. EUR 20–30 thousand, and the procedure takes several months. Certification would limit us to cooperation with one supplier of granulate, because we would certify our packaging from this granulate."* -
>
> Interview 1 (Production), Poland

Similarly, certification may be more difficult to obtain for companies from the Global South because current certification bodies are concentrated in the Global North, which may impact the financial cost and the competitiveness of Global South companies, like this interview participant described:

> *"It's inconceivable, we have all this movement, and in Brazil we do not have a certifier for our products, we do not have the biodegradability certification. If I want the certification, I have to file my application in the US or the European Union, as we do not have anything like that in Brazil, we simply have a rule that was copied, so I think it needs a set of private incentive agencies."* -
>
> Interview 14 (Production), Brazil

4.3.2 | Regulatory overhaul

Only Brazil has a regulation that restricts the labelling of compostable plastics to those that are certified (Sarantópoulos & Rego, 2020). A regulation on plastic labelling is being developed in Canada and is anticipated to only allow plastics to be labelled as compostable if they meet certification standards (Environment and Climate Change Canada, 2023b). While having a regulation in place is a good first step, the lack of enforcement was brought up as a problem in Brazil during Lab 1. For example, the National Policy on Solid Waste (NPSW) was created in 2010 to support reverse logistics and shared extended producer responsibility in the management of solid waste (Lima et al., 2021). However, the lack of specific responsibilities for each stakeholder in the NPSW poses challenges in effectively enforcing the reinsertion of materials into the post-consumer market (Matias et al., 2022). This absence of clarity hinders efficient implementation efforts. As this lab participant describes, new laws must be enforceable to be effective:

> *"See the example of the PNRS [Política Nacional de Resíduos Sólidos - Brazilian Solid Waste Legislation], which is a consistent law, (…) Even so, there is a lack of supervision by the public authorities. I am very much in favour of implementing new regulations. But for that we need very*

well-prepared legislation, and that there be proper inspection of industries." -

Participant (Waste Management), Lab 1, Brazil

Regulations are introduced under the assumption that certification standards are realistic for field conditions and for a wide variety of products. If that is not the case, as elaborated by this interview participant, then certified products may not fully break down in biowaste processing facilities:

> *"It needs to be the standard so everywhere in the world every person can actually refer to what condition we are talking about, what timeline we are talking about. So, that's what we do and then we go another step which is testing the final product itself because the material can basically pass that ASTM D6400 and get BPI certification and so on, but it might not actually happen – the compostability of it – in an actual composting facility. And why is that? [The] thickness of the product matters, the shape factor matters, how big, how small the product is. What is the shape of the product? And so on, and so on."* -
>
> Interview 6 (Production), Canada

Standards therefore need to account for a broad range of conditions. One way to do this is through field testing. Current methods used for compostable plastic packaging certification do not include field testing, nor is there a standard protocol for carrying out field tests, although there are protocols being developed (Compost Research and Education Foundation, n.d.). However, there is strong potential for field testing to improve the reliability of certification and close the gap between rigid international standards and local compost conditions.

5 | DISCUSSION: CIRCULAR ECONOMY CHALLENGES FOR THE BIO-BASED PLASTIC PACKAGING SECTOR

Insights across the four-country study indicate that the majority of bio-based plastics are being disposed of within a linear system, with this paper able to provide further depth to studies that have shown how bioplastic waste management infrastructure has not been designed appropriately due to the lack of processing facilities or problems with how bio-based materials are processed within waste management facilities (Kakadellis et al., 2021; Lambert & Wagner, 2017; Meeks et al., 2015). Figure 3 illustrates the arrangements of the different stages of the bio-based plastic packaging sector and their position as an attempted circularity loop within a waste management system that is still dominantly linear. The aggregate dimensions connected to these various stages indicate how current actions can be considered linear or circular. This shows the woven and reinforcing nature of the competing narratives that manifest as tensions in sustainability transitions, whereby the aggregated dimensions identified are evidence of how the dominant economic paradigm acts to impede progress towards circularity (Van Der Byl & Slawinski, 2015).

Whilst the steps exist to facilitate a circular system through the processing of bio-based plastic packaging as a biodegradable or compostable material, several different tensions are inhibiting their successful implementation. The findings demonstrate the circular working vision of some actors with regard to infrastructural bio-waste processing and the recycling of bio-based plastic packaging materials (shown in Figure 3 through the dashed circled lines present in all parts of the system except disposal). However, high investment costs and long payback periods are a disincentive to invest in new technology, particularly given that this may lock-in recyclers to technologies that may only be appropriate to specific materials (such as compostable

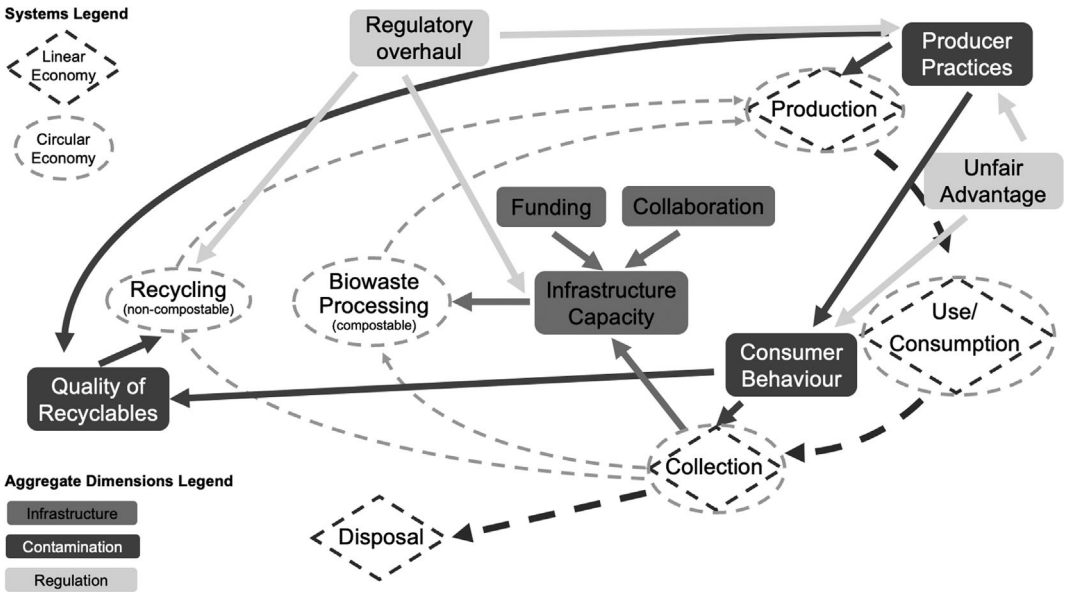


FIGURE 3 Grounded model.

materials) that hold a low market share (Taufik et al., 2020). The technicalities related to the challenges of deciphering between compostable and non-compostable materials are an active barrier for such a circular system, meaning that linear arrangements are the inevitable outcome of a system that has been unable to close the loop.

Other studies have observed how the collaborative design of products with sustainable inputs can lead to combined circular economy solutions between stakeholders (Daddi et al., 2019). However, our study showcased how such activity is disrupted through the unfair advantage of producers manufacturing products that do not meet biodegradable regulations. The limited possibilities for cascading use of bio-based products give this supply chain unique limitations, demonstrating the considerable negative implications across the supply chain of such producers in how bio-based materials that are not fully compatible with waste management infrastructure confines packaging to linear pathways. The impact of business acting in an unfair or unethical nature and the resulting tensions in the circular economy is a topic that has seen little engagement in literature (Jian et al., 2021).

Figure 3 also highlights how contamination has a widespread effect on stakeholders and processes within systems of bio-based material reuse, a new contribution to factors influencing circular economy adoption. Contamination is somewhat of an outcome of a lack of standardisation of the production of bio-based materials as well as waste treatment and recycling mechanisms. The findings are a good example of the consequences of improper attention to 'fully integrated design for remanufacture' that posits the need for the durability of design through consideration of a material's biological or technical pathways (Hopkinson et al., 2018). Given that such a piecemeal system for the recycling of bio-based materials now exists, business are in a similar position as other material reuse sectors in working towards 'moving targets' whereby "the volatility of commercial pressures, regulatory change, and faster innovation cycles requires capabilities to manage transitions back and forth as well as to realign the circular model" (Hopkinson et al., 2018, p. 88).

Figure 3 displays how a regulatory overhaul is required to demonstrate its influential connection between recycling stakeholders, infrastructural capacity and producer practices. This paper's findings contrast with other scholars who have touted third-party compliance as a successful strategy for dealing with competing narratives in circular economy transitions (Daddi et al., 2019). Producers have found it challenging to set their goals in relation to compliance with regulations given the complexity of bio-based packaging materials. Even with standards in place, the extent to which such materials are truly biodegradable is contested due to the variation in products and field conditions. Furthermore, there is unclear demand from the market given retailer and consumer confusion. Similarities can be drawn with the work of Dagilienė and Varaniūtė (2023, p. 581) in how "a tension exists between the need for companies to comply with institutional regulations and established practices and the need for companies to embrace innovations for more sustainable business practices". The institutional regulations however in the case of bio-based plastic packaging are challenging to both understand and act upon by actors across the supply chain. Whilst clear regulations may exist (such as in the case of Brazil, Canada, and Poland), their limitation in stating what bio-based plastic packaging can and cannot be on a material level does little to lead, organise and bring order to how stakeholders might be better arranged and work together to create a working circular reuse loop. The convenience of not addressing the material complexity has led to incremental, not transformational, changes which have failed to facilitate circular business models (Dagilienė & Varaniūtė, 2023).

Finally, the findings of this study showed a consistent narrative that there is great consumer confusion over how to recycle and properly dispose of bio-based and compostable packaging, as demonstrated elsewhere (Dilkes-Hoffman et al., 2019). This study also shows how this narrative has had little influence in bringing greater standardisation to the material nature of how bio-based packaging is produced as well as decipherability of the pathways through which it can be recycled. The competing narratives demonstrated in this work align with critiques of the circular economy that have noted how consumers are confronted with "hard to solve choices and trade-offs" as that the "temporality and spatiality in which consumption occurs" lacks proper acknowledgement (Corvellec et al., 2022, p. 425). This is evidence of how the transition towards greater use of bio-based packaging materials, particularly in the food sector, is framed as a novel development in the cultural norms and ethics of packaging consumption (Gurunathan et al., 2015). However, the problematic nature of the everyday material relations that consumers hold with such packaging materials, and the supporting business, regulatory and waste management arrangements, have created unrealistic expectations that consumers can take the correct actions and play their part as important actors in circular economies.

6 | CONCLUSION

This paper offered new perspectives on how current solutions are falling short of achieving circularity and system-oriented interventions that could be more effective in closing the loop for bio-based plastic packaging. Whilst bio-based plastic packaging is commonly perceived as a more sustainable alternative to conventional plastic packaging, it is currently not managed in a fully closed-loop system. Of particular concern is the widespread use of compostable plastic food packaging without proper collection and processing systems, which results in these items being disposed of as waste.

Drawing from outputs of a social innovation lab process that engaged diverse stakeholders in Brazil, Canada, Poland and the UK, an analysis of competing narratives on challenges and solutions to close the product cycle of compostable plastic food packaging was conducted. A grounded model was created to illustrate how three aggregate dimensions identified in the analysis (end-of-life processing infrastructure, contamination in processing facilities and absent or ineffective regulation) influence the circularity of bioplastics.

In most regions, end-of-life processing infrastructure is lacking or underdeveloped. Existing facilities need to be retrofitted to accommodate compostable plastic packaging, which requires high capital investments. EPR can be a mechanism to develop this infrastructure,

but it needs to be set-up at a large enough scale and to hold packaging producers accountable.

It is very difficult to visually distinguish compostable plastic packaging from other types of plastics, which has led to contamination in both recycling and biowaste processing facilities. Clearly defined, standardised labels were identified as a solution, but have limitations in being easily recognised. A more systemic solution would be to simplify packaging materials and use eco-design principles, so end-of-life management is part of the design.

Compostable plastic packaging is not currently regulated or effectively enforced (where regulations exist) in the countries where this research was conducted. The lack of regulation has created an unfair market environment for packaging. Challenges are evident with regard to the cost, accessibility, and reliability of current certification processes. Regulation and certification are important to ensure compostable plastic packaging can be properly managed in a closed-loop system, but need to be developed and implemented with equity, enforceability and practical implications in mind.

Four specific knowledge contributions are offered to understand the competing tensions limiting the transition towards circular economies. Firstly, the study's context on bio-based plastic packaging unearthed specific challenges that stakeholders are facing given the limited cascading use of this material. Secondly, the paper gives insight into the implications of unfair advantages that result from producers manufacturing materials that fail to meet regulations. Thirdly, the paper provides insight into the competing narratives regarding contamination within circular systems and how this limits circular material reuse. Finally, the study gives insight into the impact of consumer confusion over recycling sorting of bio-based plastic packaging in terms of its wider impact on the supply chain, as a critical factor that is limiting the transition towards more circular business models. Overall, by considering the case of bio-based plastic packaging in four countries, the study offers a cross-country perspective on how actors are navigating several complexities in implementing a solution. This paper offers a unique look at the barriers to achieving circularity where there is differentiation and confusion over the material make up and waste processing pathway of the material itself.

ACKNOWLEDGMENTS

The authors thank the interview and social innovation lab participants for their valuable insights and research assistants for their support in facilitation, note-taking and transcription.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ORCID

Belinda Li https://orcid.org/0000-0003-2512-5689
Macarena Beltran https://orcid.org/0000-0003-4368-1742
Benny Tjahjono https://orcid.org/0000-0001-7503-7500

REFERENCES

Allison, A. L., Lorencatto, F., Michie, S., & Miodownik, M. (2021). Barriers and enablers to buying biodegradable and compostable plastic packaging. *Sustainability*, *13*(3), 1463. https://doi.org/10.3390/su13031463

Atiwesh, G., Mikhael, A., Parrish, C. C., Banoub, J., & Le, T.-A. T. (2021). Environmental impact of bioplastic use: A review. *Heliyon*, *7*(9), e07918. https://doi.org/10.1016/j.heliyon.2021.e07918

Backhaus, J., Böschen, S., Herres-Pawlis, S., Stefan, J., & Tkachenko, N. (2023). Squaring the circle of closing the loop: The synchronization of Living Labs along the material cycle of bioplastics. Presented at the SCORAI-ERSCP-WUR conference 'Transforming consumption-production systems towards just and sustainable futures', Wageningen, Netherlands.

Barreiro-Gen, M., & Lozano, R. (2020). How circular is the circular economy? Analysing the implementation of circular economy in organisations. *Business Strategy and the Environment*, *29*(8), 3484–3494. https://doi.org/10.1002/bse.2590

Baskoro, M. L., Tjahjono, B., Beltran, M., Bogush, A., & Wang, Y. (2023). The imperative of communication signals in boosting business strategies of the bioplastic packaging industry. *Business Strategy and the Environment*, *33*(2), 307–334. Portico. https://doi.org/10.1002/bse.3490

BBIA. (2024). Welcome to the Bio-based and Biodegradable Industries Association (BBIA). Retrieved 7 March 2024, from https://bbia.org.uk/.

Beltrame, M. J. L., Beltrame, K. G., & Carvalho Oliveira, F. (2019, September 18). Composting in Brazil. BioCycle. Retrieved from https://www.biocycle.net/composting-in-brazil/, https://www.biocycle.net/composting-in-brazil/.

Beltran, M., Tjahjono, B., Bogush, A., Julião, J., & Teixeira, E. L. S. (2021). Food Plastic Packaging Transition towards Circular Bioeconomy: A Systematic Review of Literature. *Sustainability*, *13*(7), 3896. https://doi.org/10.3390/su13073896

Bishop, G., Styles, D., & Lens, P. N. L. (2022). Land-use change and valorisation of feedstock side-streams determine the climate mitigation potential of bioplastics. *Resources, Conservation and Recycling*, *180*, 106185. https://doi.org/10.1016/j.resconrec.2022.106185

Brizga, J., Hubacek, K., & Feng, K. (2020). The unintended side effects of bioplastics: Carbon, land, and water footprints. *One Earth*, *3*(1), 45–53. https://doi.org/10.1016/j.oneear.2020.06.016

Buelow, S., Lewis, H., & Sonneveld, K. (2010). The role of labels in directing consumer packaging waste. *Management of Environmental Quality: an International Journal*, *21*(2), 198–213. https://doi.org/10.1108/14777831011025544

Canada Plastics Pact. (2021). Roadmap to 2025: A shared action plan for building a circular economy for plastics packaging. Retrieved from https://roadmap.plasticspact.ca/wp-content/uploads/2021/10/CPP_Roadmap_V1_Oct2021.pdf.

Circular Bio-based Europe. (2022). Bio-based industries joint undertaking: Driving Europe's green transition. Retrieved from https://www.cbe.europa.eu/system/files/2022-12/BBI%20JU%20Driving%20Europe's%20green%20transition.pdf.

Compost Research and Education Foundation. (n.d.). Join the compostable field testing program. Retrieved 23 March 2022, from https://www.compostfoundation.org/FieldTesting.

Correa, C. A., De Oliveira, M. A., Jacinto, C., & Mondelli, G. (2022). Challenges to reducing post-consumer plastic rejects from the MSW selective collection at two MRFs in São Paulo city, Brazil. *Journal of Material Cycles and Waste Management*, *24*(3), 1140–1155. https://doi.org/10.1007/s10163-022-01387-9

Corvellec, H., Stowell, A. F., & Johansson, N. (2022). Critiques of the circular economy. *Journal of Industrial Ecology*, *26*(2), 421–432. https://doi.org/10.1111/jiec.13187

Daddi, T., Ceglia, D., Bianchi, G., & de Barcellos, M. D. (2019). Paradoxical tensions and corporate sustainability: A focus on circular economy

business cases. *Corporate Social Responsibility and Environmental Management*, *26*(4), 770–780. https://doi.org/10.1002/csr.1719

Dagilienė, L., & Varaniūtė, V. (2023). Transitioning to a circular economy: Paradoxical tensions of the circular business model. *Organization & Environment*, *36*(4), 559–589. https://doi.org/10.1177/10860266231213108

De Angelis, R. (2021). Circular economy and paradox theory: A business model perspective. *Journal of Cleaner Production*, *285*, 124823. https://doi.org/10.1016/j.jclepro.2020.124823

Dentoni, D., & Bitzer, V. (2015). The role(s) of universities in dealing with global wicked problems through multi-stakeholder initiatives. *Journal of Cleaner Production*, *106*, 68–78. https://doi.org/10.1016/j.jclepro.2014.09.050

Department for Environment, Food & Rural Affairs. (2023, November 21). Consultation outcome: Government response. Retrieved 7 March 2024, from https://www.gov.uk/government/consultations/consistency-in-household-and-business-recycling-in-england/outcome/government-response.

Dilkes-Hoffman, L., Ashworth, P., Laycock, B., Pratt, S., & Lant, P. (2019). Public attitudes towards bioplastics – Knowledge, perception and end-of-life management. *Resources, Conservation and Recycling*, *151*, 104479. https://doi.org/10.1016/j.resconrec.2019.104479

Domanski, D., Howaldt, J., & Kaletka, C. (2020). A comprehensive concept of social innovation and its implications for the local context – On the growing importance of social innovation ecosystems and infrastructures. *European Planning Studies*, *28*(3), 454–474. https://doi.org/10.1080/09654313.2019.1639397

Environment and Climate Change Canada. (2022). Consultation paper: Towards Canada-wide rules to strengthen recycling and composting of plastics through accurate labelling. Retrieved from https://www.canada.ca/content/dam/eccc/documents/pdf/cepa/consultationplasticproductreg/Labelling%20consultation%20paper_final%20EN.pdf.

Environment and Climate Change Canada. (2023a). Single-use plastics prohibition regulations: Technical guidelines. Retrieved from https://publications.gc.ca/collections/collection_2023/eccc/En14-494-1-2023-1-eng.pdf.

Environment and Climate Change Canada. (2023b, April 18). Recycled content and labelling rules for plastics. Retrieved 20 April 2023, from https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/recycled-content-labelling-rules-plastics.html.

European Committee for Standardization. (2000). EN 13432:2000 Packaging—Requirements for packaging recoverable through composting and biodegradation—Test scheme and evaluation criteria for the final acceptance of packaging.

European Parliament and Council. (1994). On packaging and packaging waste. Directive 94/62/EC §.

Findrik, E., & Meixner, O. (2023). Drivers and barriers for consumers purchasing bioplastics – A systematic literature review. *Journal of Cleaner Production*, *410*, 137311. https://doi.org/10.1016/j.jclepro.2023.137311

Gerassimidou, S., Martin, O. V., Chapman, S. P., Hahladakis, J. N., & Iacovidou, E. (2021). Development of an integrated sustainability matrix to depict challenges and trade-offs of introducing bio-based plastics in the food packaging value chain. *Journal of Cleaner Production*, *286*, 125378. https://doi.org/10.1016/j.jclepro.2020.125378

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Główny Urząd Statystyczny. (2022). Ochrona środowiska 2022 [Data set]. Retrieved from https://publikacje.new.stat.gov.pl/publikacje/ochrona-srodowiska-2022.

Goel, V., Luthra, P., Kapur, G. S., & Ramakumar, S. S. V. (2021). Biodegradable/bio-plastics: Myths and realities. *Journal of Polymers and the Environment*, *29*(10), 3079–3104. https://doi.org/10.1007/s10924-021-02099-1

Government of Ontario. (2023). Ontario Regulation 391/21. O. Reg. 391/21 §.

Grin, J., Rotmans, J., & Schot, J. (2010). Theoretical backgrounds: Science and technology studies, evolutionary economics and sociology. In *Transitions to sustainable development: New directions in the study of long term transformative change (0 ed.)*. Routledge. https://doi.org/10.4324/9780203856598

Gurunathan, T., Mohanty, S., & Nayak, S. K. (2015). A review of the recent developments in biocomposites based on natural fibres and their application perspectives. *Composites Part a: Applied Science and Manufacturing*, *77*, 1–25. https://doi.org/10.1016/j.compositesa.2015.06.007

Hinderer, S., & Kuckertz, A. (2022). The bioeconomy transformation as an external enabler of sustainable entrepreneurship. *Business Strategy and the Environment*, *31*(7), 2947–2963. https://doi.org/10.1002/bse.3056

Hopkinson, P., Zils, M., Hawkins, P., & Roper, S. (2018). Managing a complex global circular economy business model: Opportunities and challenges. *California Management Review*, *60*(3), 71–94. https://doi.org/10.1177/0008125618764692

Hottle, T. A., Bilec, M. M., & Landis, A. E. (2013). Sustainability assessments of bio-based polymers. *Polymer Degradation and Stability*, *98*(9), 1898–1907. https://doi.org/10.1016/j.polymdegradstab.2013.06.016

Jian, J., Li, B., Zhang, N., & Su, J. (2021). Decision-making and coordination of green closed-loop supply chain with fairness concern. *Journal of Cleaner Production*, *298*, 126779. https://doi.org/10.1016/j.jclepro.2021.126779

Jordan-Kulczyk, K., Zając, O., Kotlarek, M., Lemańska, M., Dłutowska, J., Małecka, P., … Wilczek, M. (2021). Consumers' adaptability to sustainability in fashion. Retrieved from https://web-assets.bcg.com/27/f3/794284e7437d99a71d625caf589f/consumers-adaptation-to-sustainability-in-fashion.pdf.

Kakadellis, S., Woods, J., & Harris, Z. M. (2021). Friend or foe: Stakeholder attitudes towards biodegradable plastic packaging in food waste anaerobic digestion. *Resources, Conservation and Recycling*, *169*, 105529. https://doi.org/10.1016/j.resconrec.2021.105529

Kędzia, G., & Turek, J. (2022). What Hinders the Development of a Sustainable Compostable Packaging Market? *European Journal of Sustainable Development*, *11*(4), 180. https://doi.org/10.14207/ejsd.2022.v11n4p180

Kochańska, E., Łukasik, R. M., & Dzikuć, M. (2021). New circular challenges in the development of take-away food packaging in the COVID-19 period. *Energies*, *14*(15), 4705. https://doi.org/10.3390/en14154705

Kochanska, E., Wozniak, K., Nowaczyk, A., Piedade, P. J., De Almeida Lavorato, M. L., Almeida, A. M., … Lukasik, R. M. (2022). Global ban on plastic and what next? Are consumers ready to replace plastic with the second-generation bioplastic? Results of the snowball sample consumer research in China, Western and Eastern Europe, North America and Brazil. *International Journal of Environmental Research and Public Health*, *19*(21), 13970. https://doi.org/10.3390/ijerph192113970

La Fuente, C. I. A., Tribst, A. A. L., & Augusto, P. E. D. (2022). Knowledge and perception of different plastic bags and packages: A case study in Brazil. *Journal of Environmental Management*, *301*, 113881. https://doi.org/10.1016/j.jenvman.2021.113881

Lackner, M., Mukherjee, A., & Koller, M. (2023). What are "bioplastics"? Defining renewability, biosynthesis, biodegradability, and biocompatibility. *Polymers*, *15*(24), 4695. https://doi.org/10.3390/polym15244695

Lambert, S., & Wagner, M. (2017). Environmental performance of bio-based and biodegradable plastics: The road ahead. *Chemical Society Reviews*, *46*(22), 6855–6871. https://doi.org/10.1039/C7CS00149E

Law, K. L., & Narayan, R. (2021). Reducing environmental plastic pollution by designing polymer materials for managed end-of-life. *Nature Reviews Materials*, *7*(2), 104–116. https://doi.org/10.1038/s41578-021-00382-0

Leipold, S., Weldner, K., & Hohl, M. (2021). Do we need a 'circular society'? Competing narratives of the circular economy in the French food sector. *Ecological Economics*, *187*, 107086. https://doi.org/10.1016/j.ecolecon.2021.107086

Li, B., Soma, T., Springle, N., & Shulman, T. (2023). Reflections From Implementing a Virtual Social Innovation Lab. *International Journal of Qualitative Methods*, *22*, 160940692211498. https://doi.org/10.1177/16094069221149871

Liliani, Tjahjono, B., & Cao, D. (2020). Advancing bioplastic packaging products through co-innovation: A conceptual framework for supplier-customer collaboration. *Journal of Cleaner Production*, *252*, 119861. https://doi.org/10.1016/j.jclepro.2019.119861

Lima, L. R., Gutierrez, R. F., & Cruz, S. A. (2021). Challenges in the context of single-use plastics and bioplastics in Brazil: A legislative review. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, *40*(7), 998–1006. https://doi.org/10.1177/0734242x211055548

Lima, L. R., Gutierrez, R. F., & Cruz, S. A. (2022). A Perspective of the COVID-19 Pandemic in the Plastic Waste Management and Cooperatives of Waste Pickers in Brazil. *Circular Economy and Sustainability*, *2*(3), 903–913. https://doi.org/10.1007/s43615-021-00130-0

Liu, W., Zhu, Z., & Ye, S. (2023). A Framework Towards Design for Circular Packaging (DfCP): Design Knowledge, Challenges and Opportunities. *Circular Economy and Sustainability*, *3*(4), 2109–2125. https://doi.org/10.1007/s43615-023-00264-3

Luo, Y., Zelenika, I., & Zhao, J. (2019). Providing immediate feedback improves recycling and composting accuracy. *Journal of Environmental Management*, *232*, 445–454. https://doi.org/10.1016/j.jenvman.2018.11.061

Major, D. (2023, November 16). Judge says Ottawa listing plastic items as toxic was 'unreasonable and unconstitutional'. CBC News. Retrieved from https://www.cbc.ca/news/politics/court-rules-against-listing-plastics-as-toxic-1.7030716.

Matias, M. S., Pincelli, I. P., Lange, L. C., Ferreira, J. A., & Junior, A. B. D. C. (2022). Solid waste policy in Brazil: Learnings and challenges after a decade of implementation. *International Journal of Environment and Waste Management*, *30*(2), 168–190. https://doi.org/10.1504/IJEWM.2022.128212

McGann, M., Blomkamp, E., & Lewis, J. M. (2018). The rise of public sector innovation labs: Experiments in design thinking for policy. *Policy Sciences*, *51*(3), 249–267. https://doi.org/10.1007/s11077-018-9315-7

Meeks, D., Hottle, T., Bilec, M. M., & Landis, A. E. (2015). Compostable biopolymer use in the real world: Stakeholder interviews to better understand the motivations and realities of use and disposal in the US. *Resources, Conservation and Recycling*, *105*, 134–142. https://doi.org/10.1016/j.resconrec.2015.10.022

Miro. (n.d.). Business Model Canvas Template. Retrieved 9 July 2023, from https://miro.com/templates/business-model-canvas/.

Moggi, S., & Dameri, R. P. (2021). Circular business model evolution: Stakeholder matters for a self-sufficient ecosystem. *Business Strategy and the Environment*, *30*(6), 2830–2842. https://doi.org/10.1002/bse.2716

Nesti, G. (2018). Co-production for innovation: The urban living lab experience*. *Policy and Society*, *37*(3), 310–325. https://doi.org/10.1080/14494035.2017.1374692

Nogueira, L. A., Lindeløv, B., & Olsen, J. (2023). From waste to market: Exploring markets, institutions, and innovation ecosystems for waste valorization. *Business Strategy and the Environment*, *32*(4), 2261–2274. https://doi.org/10.1002/bse.3247

Pinkse, J., & Bohnsack, R. (2021). Sustainable product innovation and changing consumer behavior: Sustainability affordances as triggers of adoption and usage. *Business Strategy and the Environment*, *30*(7), 3120–3130. https://doi.org/10.1002/bse.2793

Polish Chamber of Packaging. (2019). Biuletyn Opakowaniowy, Vol. 1, No. 137. Retrieved from https://www.pakowanie.info/uploads/1/0/2/5/10250887/biuletyn_-_2019-01_-_internet.pdf.

Portal Komunalny. (2022, January 28). BDO - aktualna lista kodów odpadów. Wybór kodu w 3 krokach. Retrieved 29 January 2024, from https://portalkomunalny.pl/kody-odpadow-bdo-430842/.

Prieto, A. (2016). To be, or not to be biodegradable … that is the question for the bio-based plastics. *Microbial Biotechnology*, *9*(5), 652–657. https://doi.org/10.1111/1751-7915.12393

Puntillo, P., Gulluscio, C., Huisingh, D., & Veltri, S. (2021). Reevaluating waste as a resource under a circular economy approach from a system perspective: Findings from a case study. *Business Strategy and the Environment*, *30*(2), 968–984. https://doi.org/10.1002/bse.2664

Raźniewska, M. (2022). Compostable Packaging Waste Management—Main Barriers, Reasons, and the Potential Directions for Development. *Sustainability*, *14*(7), 3748. https://doi.org/10.3390/su14073748

Recycle BC. (2019). Compostable packaging and paper product: 2019 Research summary report. Retrieved from http://recyclebc.ca/wp-content/uploads/2020/06/Compostable-Packaging-2019-Research-Summary-Report_Final.pdf.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169. https://doi.org/10.1007/BF01405730

Sarantópoulos, C. I. G. L., & Rego, R. A. (Eds.). (2020). Brasil Pack Trends 2020. Retrieved from http://ital.agricultura.sp.gov.br/brasilpacktrends/en/.

Schmidt, J., Grau, L., Auer, M., Maletz, R., & Woidasky, J. (2022). Multilayer packaging in a circular economy. *Polymers*, *14*(9), 1825. https://doi.org/10.3390/polym14091825

Simms, C., Trott, P., van den Hende, E., & Hultink, E. J. (2020). Barriers to the adoption of waste-reducing eco-innovations in the packaged food sector: A study in the UK and the Netherlands. *Journal of Cleaner Production*, *244*, 118792. https://doi.org/10.1016/j.jclepro.2019.118792

Skouloudis, A., Malesios, C., Lekkas, D.-F., & Panagiotopoulou, A. (2023). Consumer preferences in Greece for bio-based products: A short communication. *Circular Economy and Sustainability*, *3*(2), 1065–1076. https://doi.org/10.1007/s43615-022-00215-4

Smol, M., Kulczycka, J., Czaplicka-Kotas, A., & Włóka, D. (2019). Zarządzanie i monitorowanie gospodarki odpadami komunalnymi w Polsce w kontekście realizacji gospodarki o obiegu zamkniętym (GOZ). *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi Polskiej Akademii Nauk*, *108*, 165–184. https://doi.org/10.24425/znigsme.2019.130174

Spierling, S., Knüpffer, E., Behnsen, H., Mudersbach, M., Krieg, H., Springer, S., Albrecht, S., Herrmann, C., & Endres, H.-J. (2018). Bio-based plastics—A review of environmental, social and economic impact assessments. *Journal of Cleaner Production*, *185*, 476–491. https://doi.org/10.1016/j.jclepro.2018.03.014

Springle, N., Li, B., Soma, T., & Shulman, T. (2022). The complex role of single-use compostable bioplastic food packaging and foodservice ware in a circular economy: Findings from a social innovation lab. *Sustainable Production and Consumption*, *33*, 664–673. https://doi.org/10.1016/j.spc.2022.08.006

Styś, T., Foks, R., & Moskwik, K. (2018). Krajowy Pan Gospodarki Odpadami. Retrieved from https://www.sobieski.org.pl/wp-content/uploads/2018/08/Stys-Foks-Moskwik-KPGO-2030-PDF.pdf.

Suchek, N., Fernandes, C. I., Kraus, S., Filser, M., & Sjögrén, H. (2021). Innovation and the circular economy: A systematic literature review. *Business Strategy and the Environment*, *30*(8), 3686–3702. https://doi.org/10.1002/bse.2834

Szincel, K. (2021, August 9). Analiza odpadów komunalnych w raporcie Ochrony Środowiska. Retrieved 1 August 2024, from SegreGO

website: https://segrego.pl/analiza-odpadow-komunalnych-w-raporcie-ochrony-srodowiska/.

Tan, J., Tiwari, S. K., & Ramakrishna, S. (2021). Single-use plastics in the food services industry: Can it be sustainable? *Materials Circular Economy*, *3*(1), 7. https://doi.org/10.1007/s42824-021-00019-1

Tardy, B. L., Richardson, J. J., Greca, L. G., Guo, J., Bras, J., & Rojas, O. J. (2022). Advancing bio-based materials for sustainable solutions to food packaging. *Nature Sustainability*, *6*(4), 360–367. https://doi.org/10.1038/s41893-022-01012-5

Taufik, D., Reinders, M. J., Molenveld, K., & Onwezen, M. C. (2020). The paradox between the environmental appeal of bio-based plastic packaging for consumers and their disposal behaviour. *Science of the Total Environment*, *705*, 135820. https://doi.org/10.1016/j.scitotenv.2019.135820

TechSci Research LLC. (2023, November). Canada compostable plastics market to grow with a CAGR of 3.61% through 2028. Retrieved 19 January 2024, from https://www.techsciresearch.com/news/14606-canada-compostable-plastics-market.html.

Tjahjono, B., Beltran, M., Lazell, J., Bek, D., & Bogush, A. (2022). Prototyping Solutions – Findings from the third UK SIMBIO social innovation lab – and SIMBIO project implications, 25th of November, 2021. Retrieved from https://pure.coventry.ac.uk/ws/portalfiles/portal/56857107/SIMBIO3_Prototyping_Solutions.pdf.

Tkaczyk, S., Kuzincow, J., & Ganczewski, G. (2014). Life cycle assessment in management of socially responsible enterprise. *Foundations of Management*, *6*(3), 71–82. https://doi.org/10.1515/fman-2015-0019

Van Der Byl, C. A., & Slawinski, N. (2015). Embracing tensions in corporate sustainability: A review of research from win-wins and trade-offs to paradoxes and beyond. *Organization & Environment*, *28*(1), 54–79. https://doi.org/10.1177/1086026615575047

Van Roijen, E. C., & Miller, S. A. (2022). A review of bioplastics at end-of-life: Linking experimental biodegradation studies and life cycle impact assessments. *Resources, Conservation and Recycling*, *181*, 106236. https://doi.org/10.1016/j.resconrec.2022.106236

Walker, S., & Rothman, R. (2020). Life cycle assessment of bio-based and fossil-based plastic: A review. *Journal of Cleaner Production*, *261*, 121158. https://doi.org/10.1016/j.jclepro.2020.121158

Walker, T. R., McGuinty, E., Charlebois, S., & Music, J. (2021). Single-use plastic packaging in the Canadian food industry: Consumer behavior and perceptions. *Humanities and Social Sciences Communications*, *8*(1), 80. https://doi.org/10.1057/s41599-021-00747-4

Westley, F., & Laban, S. (2015). Social innovation lab guide. Waterloo Institute for Social Innovation and Resilience. Retrieved from Waterloo Institute for Social Innovation and Resilience website: https://uwaterloo.ca/waterloo-institute-for-social-innovation-and-resilience/sites/ca.waterloo-institute-for-social-innovation-and-resilience/files/uploads/files/10_silabguide_final.pdf.

WRAP. (2024). The UK Plastic Pact. Retrieved 22 August 2024, from https://www.wrap.ngo/taking-action/plastic-packaging/initiatives/the-uk-plastics-pact.

Wu, D. W.-L., Lenkic, P. J., DiGiacomo, A., Cech, P., Zhao, J., & Kingstone, A. (2018). How does the design of waste disposal signage influence waste disposal behavior? *Journal of Environmental Psychology*, *58*, 77–85. https://doi.org/10.1016/j.jenvp.2018.07.009

How to cite this article: Li, B., Lazell, J., Beltran, M., Kędzia, G., Lima, L. R., Soma, T., Cruz, S. A., Gutierrez, R. F., Turek, J., Raźniewska, M., Pluta-Zaremba, A., & Tjahjono, B. (2024). Competing narratives inhibit a circular economy for bio-based plastic packaging: Insights from a social innovation lab study in Brazil, Canada, Poland and the UK. *Business Strategy and the Environment*, 1–39. https://doi.org/10.1002/bse.3997

APPENDIX A.

TABLE A1. Brazil lab 1.

Time	Activity	Description	Key findings
10 min	Opening	Reception of participants on the Zoom platform and waiting time for the start.	• not applicable
20 min	Initial presentation	Team presentation on the project objectives and findings through interviews with key informants and convening questions. The main points in common vs polarities were explained through analysis of categories: Cost; replacing conventional plastics with bioplastics; solution or problem?; alternatives; public policies involved; environmental and social impact.	• not applicable
45 min	Division into subgroups (3 groups divided with different stakeholders mediated by a team member)	Discuss in each group the dilemma questions: 1. How can we advance in the discussion of legislation and creation of norms, while there is a lack of understanding for society, in general, about the terms and types of bioplastics? 2. How can we correctly dispose of waste and expand recycling, while there is a need to create conditions for composting and there is no trade for some types of post-consumer packaging? In addition to avoiding the impact on waste pickers' cooperatives 3. How can we expand the production and consumption of bio-packaging, while having a high cost and difficulty in standardising the process? 4. How can we reduce the cost, while there is difficulty in scaling and there are few tax incentives for the industry? Suggest discussions: *what do you agree with? *what is missing? What would you add? *what are your covening questions? Discussion completion using MIRO interactive whiteboard support	• finding-gaps and finding-ideas: ◦ better outline the correct definitions for each type of bioplastic, before defining better legislation; ◦ national versions (ABNT standard) are missing for all type of bioplastics and their classifications, as well as the biodegradability seal; ◦ expose and raise awareness not only among consumers, but also among legislators; ◦ better understanding and meaning of biopolymers; ◦ prevent forgery, fraud and greenwashing; ◦ ban or surcharge single-use plastics; ◦ effectiveness in labelling so that society understands the standards; ◦ life cycle analysis for better decision making; ◦ disseminated information to better understand the added value of bioplastics compared to conventional single-use plastics; ◦ add value to biopolymer waste, applying reverse logistics by companies and startups; ◦ decentralise cooperatives and recyclers to avoid greater impact on waste pickers; ◦ increase competitiveness with tax breaks; ◦ surcharge on the disposal of conventional plastics; ◦ reducing taxes on imports of biopolymers.
30 min	Report Back (10 min each member team)	Moderators explain the results of their group's discussion by presenting the MIRO interactive whiteboard obtained	• not applicable
15 min	Final considerations	Presentation of next steps, reinforcing the importance of each stakeholder. Thanks to the participants for their participation. Open for questions/doubts and considerations about the workshop.	• not applicable

TABLE A2. Brazil lab 2.

Time	Activity	Description	Key findings
10 min	Opening	Reception of participants on the Zoom platform and waiting time for the start	• not applicable
15 min	1st step: Initial presentation	Detailed presentation of the issues raised in lab 1	• not applicable
90 min	2nd step (discussion session)	a) in terms of legislation and for bioplastics to become competitive in the market, some participants suggested surcharges on the production of conventional plastics. Faced with this issue, the key question is: How could this solution be put into practice? What are the barriers, what resources are needed and who needs to be involved? a-1) participants will use Mentimeter to respond in a few words: In addition to surcharges, what other measure/ proposal could be applied in terms of legislation? (leave open) b) for the legislation to be effective, the stakeholders proposed that society understand the existing rules and how the phenomenon of biodegradation happens, justifying that consumers will be able to choose more consciously for their products/packaging. Faced with this issue, the key questions are: How can we develop effective environmental education projects for large masses? What are the barriers, the resources needed and who needs to be involved in these projects? b-1) Mentimeter: What other ways to raise awareness in society and reach large masses to disseminate information in this context? c) in terms of management and correct disposal of waste and the impact that it may have on cooperatives and waste pickers in the future, one of the solutions discussed in lab 1 was the application of reverse logistics by bioplastic companies and industries. Reverse logistics are already seldomly used for conventional materials and plastics. Faced with this issue, the key question is: Thinking about the future scenario and taking into account that there will be an increase in the consumption of biodegradable bioplastics, how can waste pickers and cooperatives be included in the management process and reverse logistics for these materials? What types of packaging are important to replace and how to include waste pickers in the collection of biodegradables? Which actors do we need to involve so that an effective solution to this dilemma is outlined? (thinking about a future scenario, with the expansion of bioplastic production and possible replacement for some packaging, how to guarantee waste pickers and cooperatives…) c-1) Mentimeter: In addition to reverse logistics, what other solution would be relevant to avoid the impact on cooperatives and the income of waste pickers? d) in terms of cost, stakeholders pointed out that a prohibitive factor in the market is the issue of scaling and standardising processes. Faced with this issue, the key question is: What is missing for Brazil to reach a biodegradable and compostable scale? What are the barriers, the resources needed and who needs to be involved to solve this dilemma? d-1) Mentimeter: What are the main obstacles to expanding the market for compostables in Brazil? Thinking beyond the cost…	a) Taxes on single-use plastics: • Main impacted: ◦ Commodity market; ◦ Population of classes B and C (economically lowest). • Key partners: ◦ Associations; ◦ Industries responsible for single-use; ◦ Consumers; ◦ Government. • Key barriers: ◦ Lack of adhesion from those involved; ◦ Consumers still do not understand the alternatives; ◦ Improve the cost and accessibility of new technologies. b) Raising awareness in society: • Effective actions: ◦ Disseminate information - all actors involved; ◦ Insert courses on the environment in basic education; ◦ Provide icons on packaging for proper disposal; ◦ Discussion forums without excluding the most marginalised; ◦ Projects in schools and condominiums. • Key partners and key resources: ◦ Environmental associations; ◦ Social media; ◦ Marketing by startups; ◦ Universities; ◦ Research centres; ◦ Large industries/major players; ◦ Government; ◦ Waste picker cooperatives. • Key barriers: ◦ Management and government; ◦ Municipal and state laws; ◦ Change of government and social disruption; ◦ Lack of knowledge, training and qualifications of educators on the subject. c) Impact on waste picker cooperatives (marginalised professionals): • Key gaps: ◦ Partnerships between municipal management and selective collection by waste pickers; ◦ Inclusion of waste pickers in debates about market transition in new packaging technologies. • Key training: ◦ Short courses with illustrative booklets; ◦ Easy-to-understand banners to identify different types of materials; ◦ Integration and dynamic actions involving associations and other actors involved in the chain. • Key barriers: ◦ Need for recognition of the work of cooperatives and waste pickers; ◦ Lack of support for collection-transport-separation processes;

(Continues)

(Continued)

Time	Activity	Description	Key findings
			○ Non-payment for each process and service provided by waste pickers. d) Market growth: • Gaps in scheduling ○ Increased volume does not guarantee affordable prices; ○ Process bottlenecks: Inputs, equipment, qualified labour, etc.; ○ Competing with commodities is unfair in the current scenario; ○ Planning: Production, distribution, consumption and disposal; ○ Avoid incorrect flow that continues to harm the environment. • Key partners: ○ Government, universities and industries with effective communication; ○ Innovation incentive agencies; ○ Government regulatory agencies; ○ Research centres; ○ Support entrepreneurs. • Key barriers: ○ Investment in new technologies by the private sector and the government; ○ Investment in new equipment and machinery; ○ Distance between universities and companies; ○ Tax breaks; ○ Encouraging entrepreneurship; ○ Consumer interest; ○ Practice of greenwashing.
30 min	3rd step (reflections)	Bring a final reflection to everyone, and ask participants to consider the next 10 years, and ask them how they see these solutions and the scenario in Brazil until 2030? What other solutions would be important to be taken? What resources could we use in the social innovation lab to gain traction? Who can we involve to ensure greater success?	• Key beliefs: ○ Biopolymers are part of the solution, especially with regard to marine pollution and the impact on fauna; ○ Mainly biopolymers produced from waste will positively impact a circular economy and reduce the consumption of non-renewable sources; ○ Gradual increase in the production and application of biopolymers in disposable packaging; ○ Each Brazilian municipality (among the 5,530 in the country), has at least one waste pickers cooperative been paid for the collection, separation/sorting of waste, or any other service provided (hiring cooperatives would reduce unemployment in the country); ○ Governments that are more competent and committed to the environment, social issues and with more responsibilities than current administrations have; ○ More incentives for research and development of new materials, with increased investments in the packaging sector based on biopolymers; ○ Return of paper packaging, returnable bags and improvements in the world's environmental issues; ○ Brazil is no longer sending waste to landfills and by 2030 there will be a significant increase in recycling and composting. • Key solutions: ○ Greater involvement of public managers for more committed legislation for biodegradable and compostable materials;

(Continued)

Time	Activity	Description	Key findings
			○ Shared responsibility together with public authorities and citizens; ○ Mandatory separation of wet and dry waste, and how managers should demand this practice from citizens, through more effective laws and public policies.
5 min	Closing session	Next steps of research (lab 3). Thank stakeholders for their participation.	• Not applicable

TABLE A3. Brazil lab 3.

Time	Activity	Description	Key findings
15 min	Opening	Reception of participants at the event and on Zoom platform and waiting time for the start	• Not applicable
45 min	Legislation presentations and discussion	Presentation 1: Bioplastics and the reverse logistics of packaging in general Presentation 2: Integrated Management of Municipal Waste in a post-pandemic scenario: Case of Santo André Discussion with in-person and online attendees with remaining time following presentations	• Prioritise: Non-generation of waste, reduction, reuse, recycling, treatment, final disposal (with energy reuse); • Offer post-consumer waste return channels for the industry; • Encourage companies, mainly transnational ones, to adopt sustainable practices; • Sectoral agreement by Brazilian associations: Reduce packaging in general, with a reduction of at least 22% of packaging disposed of in landfills; • Certification and seals for different types of bioplastics to generate the correct destination (recycling x composting) and avoid microplastics; barrier: There are not enough composting plants active in Brazil • Avoid waste contamination: The use of biodegradable materials in the manufacture of packaging cannot damage the recycling of conventional packaging; • Mandatory reverse logistics: The use of biodegradable materials in the manufacture of packaging must be accompanied by reverse logistics actions that guarantee the composting of this waste to meet the goals defined in the legislation (collection of post-consumer packaging placed on the market) with adequate disposal and landfill diversion.
90 min	Markets presentations and discussion	Presentation 1: Innovation and sustainability in practice: Learn about cassava bio-packaging Presentation 2: Bio-polyamide from a renewable source for engineering plastics and Fibres Presentation 3: BioSmart: A startup based on biopolymers Presentation 4: Brazil: A global platform for bioplastics Presentation 5: I'm green bio-based - bioplastic from a renewable source Discussion with in-person and online attendees with remaining time following presentations	• Support between companies towards a low-carbon economy, but what about disposal (final destination)? ○ Strategic partners in biotechnology (from packaging design); ○ Launching sustainable (compostable) packaging is not enough. There is a need for a paradigm shift in society, adaptation of consumer behaviour, customers, the supply chain, the use of renewable materials, public/private support and incentives in companies seeking change. ○ Transition the design of packaging with a very short life cycle in terms of usage time (a few minutes), very long decomposition time (hundreds of years); • Brazilian prototypes experiencing the circular economy: ○ Raw material planted by small producers and family farming, practice of polyculture, does not generate waste (generates input, fertiliser), water reduction in production, CO2 capture, national technology - biodegradable and compostable packaging in up to 90 days and can be composted in domestic compost

(Continues)

(Continued)

Time	Activity	Description	Key findings
			bins - still practices reverse logistics by converting packaging into inputs (nature's cycle, zero waste); ○ Biodegradable packaging made from bacterial cellulose, and edible packaging made from onion, papaya, among other fruits. • Barriers not yet resolved: ○ Scaling; ○ Cost; ○ Preservation of cultivable areas and preservation of food security in Brazil; ○ Greenwashing refers to regulations that still mislead consumers about the biodegradability of some types of bioplastics.
20 min	Break		• Not applicable
45 min	Waste management presentations and discussion	Presentation 1: Waste picker cooperative Presentation 2: Waste picker cooperatives for recyclable materials and the challenge with the packaging of new materials Discussion with in-person and online attendees with remaining time following presentations	• Waste pickers, whether or not organised in cooperatives, represent a fundamental element in maintaining the recycling production chain in Brazil; • Act as environmental agents, as they reduce the amount of solid waste to be disposed of in locations that are not always suitable; • Cooperatives provide the inclusion of historically excluded people; • Propositions: ○ Recognition by public authorities and society of the importance of the work of waste pickers; ○ Organisation of these workers on 3 fronts: • Inclusion in the social movement of the category; • Organisation in collective enterprises; • Organisation of cooperatives and associations into solidarity networks; ○ Contracting by municipal public authorities for services provided; ○ Implementation of reverse logistics, ○ Shared responsibility and sectoral agreements (provided for in legislation), ○ Inclusion of waste pickers in strategic plans for collecting biodegradable and compostable plastic waste, ○ Addition of regulations for the use of bioplastics and easy identification seals to avoid social impact on the category and diversion of materials that can and should be returned to the cycle.
75 min	Research and development presentations and discussion	Presentation 1: Use of food processing by-products as sources of bioplastics Presentation 2: Environmentally friendly polymers Presentation 3: Use of bioplastics in the preparation of edible films Presentation 4: Upcycling in the context of bioplastics	• Valorization of food by-products generates economy, lower environmental impact and is in line with the approach related to resource management from the perspective of sustainability (resources are interconnected); • Food waste/by-products can be used as resources to produce compostable packaging (zero waste); • Upcycling: Reusing and adding value to agro-industrial waste/by-products without competing with food. Food takes priority over materials (packaging); • Compostable and primary biopackaging prototypes: ○ Mango seed films; ○ Cashew by-product films; ○ Whole waste films (orange pomace, sugar cane pomace); ○ Edible films of cocoa pulp and cupuaçu; ○ Edible gelatin films; • Barriers: ○ Lower reproducibility due to biological, seasonal and spatial variability;

(Continued)

Time	Activity	Description	Key findings
			○ Technological challenges (component solubilization, component aggregation, etc.) to achieve materials with properties similar to the original natural structures; ○ Achieving packaging that is as good and returnable to the earth cycle as natural shells; ○ Assessment of the life cycle (environmental + economic + social) to make the correct decision on the use of compostable packaging compared to others; ○ Focus on prompt disposal and pay attention to greenwashing, always based on circularity with zero or minimum waste possible (extraction, consumption and return to nature in a fair way).
15 min	Closing	Closing remarks from the research team	• Not applicable

TABLE A4. Canada lab 1.

Time	Activity	Description	Key findings
Part A			
10 min	Opening	Participants sign into Zoom. Introduction to study and land acknowledgement.	• Not applicable
15 min	Introductions icebreaker	Participants split into 3 groups and introduce themselves by name and organisation, and two words to describe bioplastic packaging without using "taboo" words.	• Not applicable
10 min	Presentation	Introduction to findings from the key informant interviews and convening question.	• Not applicable
35 min	Group timelines	Participants split into 2 groups. Each participant makes notes on Miro about what they see as milestones on personal and societal timelines related to bioplastic packaging then post them on the timelines.	• Different ways that participants first became aware of plastic waste problems, e.g., at work, at school, living abroad, through news • Initial involvement in bioplastics life cycle at different stages, such as looking for alternatives to single-use plastics (product use), others seeing more products at waste management facilities (product end-of-life) • Key themes: ○ End-of-life management ○ Confusion ○ Regulation ○ Single-use items ○ Type of feedstock
10 min	Report Back	Facilitators share timelines of their breakout groups with the whole group.	• Not applicable
5 min	Wrap up	Thank participants for attending. Review next steps in the research process. Introduce "homework". Share survey link.	• Not applicable
Part B			
10 min	Opening	Participants sign into zoom. Introduction to study and land acknowledgement.	• Not applicable
15 min	Show-and-tell icebreaker	Participants split into 3 groups and share the 2 pieces of packaging that they found at home and their observations of how the packaging is used.	• Not applicable
5 min	Recap	Summary presentation of previous session.	• Not applicable
5 min	System mapping	Introduction to system mapping exercise.	• Not applicable
45 min	System mapping breakouts	Participants split into 3 groups. Using Miro, each group maps out the stakeholders involved and challenges/barriers that they face related to the assigned bioplastic package type.	• Key challenges/barriers: ○ Bioplastic product labelling inconsistent/not regulated

(Continues)

(Continued)

Time	Activity	Description	Key findings
5 min	Move groups	Short break and switch facilitators/notetakers to a different breakout group.	○ Lack of bioplastic research ○ Sourcing sustainable materials ○ Volatile industry and risk of lock-in to production technology ○ Consumers misinformed, do not have proper disposal channels ○ Composting facilities lacking/unwilling to take bioplastics ○ Bioplastics cannot be recycled • Key opportunities: ○ Guidelines, regulations, enforcement on labelling ○ Research that takes whole systems approach and long-term effects on soil and water ○ Connecting feedstock producers to bioplastic producers, find ways to use residues ○ Extended producer responsibility to encourage more sustainable design and ensure capture at end-of-life ○ Closing knowledge gap between consumers, bioplastic industry, waste management ○ Lab and field testing reflective of composting facility conditions
20 min	Breakouts sharing	Facilitator shares systems map with the new group. New group comments on the systems map.	
10 min	Report Back	Reporters from each breakout group share the key insights from their discussions.	
5 min	Wrap up	Thank participants for attending. Review next steps in the research process. Share survey link.	• Not applicable
Part C			
10 min	Opening	Participants sign into zoom. Introduction to study and land acknowledgement.	• Not applicable
15 min	Vision drawing icebreaker	Participants split into 3 groups and draw their vision for the ideal system of how bioplastics packaging will function in society, then share the picture with the group.	• Not applicable
5 min	Recap	Summary presentation of previous session.	• Not applicable
5 min	Leverage areas	Introduction to the concept of leverage points and "leverage areas" (where possible leverage points could be).	• Not applicable
60 min	Leverage areas	Participants split into 3 groups and discuss the "leverage areas" and identify any that may be missing or need to be changed.	• Leverage areas: ○ Differentiating bioplastic products from each other ○ Materials used to make bioplastics ○ Role of bioplastics in packaging food ○ Handling bioplastics from one stage to the next in the supply chain ○ Product design and the innovation process/pipeline
15 min	Report Back	Facilitators from each breakout group share their Miro board and key insights from their discussions.	
10 min	Wrap up	Thank participants for attending. Review next steps in the research process. Share survey link.	• Not applicable

TABLE A5. Canada lab 2.

Time	Activity	Description	Key findings
Part A			
10 min	Opening	Participants sign into Gather.Town. Introduction to study and land acknowledgement. Summary presentation of previous session.	• Not applicable
10 min	Move your avatar icebreaker	Participants move their avatars in a game to practise using the platform.	• Not applicable
10 min	Trivia	Ask trivia questions from thinking in systems. Participants that correctly answer first win prizes.	• Not applicable
10 min	Vote for solution ideas	Participants take 1 minute to reflect on general ideas for potential solutions and write them into the chat box. Facilitators organise the ideas into thematic clusters. Participants vote for which themes they are interested in the same way as move your avatar. The 3 themes with the most votes are used in the next activity.	• Solution themes (bolded items for next activity): ○ Regulation for testing, labelling, single-use items ○ Influencing purchasing and disposal consumer behaviour ○ Shifting towards alternate systems for reusables and sharing ○ Increase infrastructure for composting and its value ○ Designing for end of life ○ Small and local production
40 min	Design jam 1	Participants join one of the 3 breakout groups. Participants brainstorm more specific ideas for solutions based on the theme of their "table". Notetakers add ideas onto Miro (one per sticky note) and categorise ideas into themes.	• Regulation: ○ Regulating labelling for bioplastic products ○ Complexities around regulations for bioplastics labelling and end-of-life due to the variation among different regions and processing facilities, as well as current trends in organics processing • Consumer behaviour: ○ Social media, influencers, and ambassador programs to promote and normalise sustainable behaviour among consumers ○ School curriculums to promote circularity and gamification to encourage shifts in behaviour ○ Need to have some type of quality control on the messages that are shared • Alternate systems: ○ Reusable and shareable foodservice ware ○ Move consumers away from the dominant paradigm of single-use and disposables towards a more circular approach ○ Need to find the best quality materials and designs, and to address the beliefs and emotions of consumers to make this solution successful
10 min	Break		
20 min	Report Back 1	Reporters from each breakout group share their ideas. Other groups can ask questions.	
5 min	Bricolage	Presentation about the concept of bricolage and introduction of virtual bricolage activity.	
40 min	Design jam 2	Participants go back to breakout groups and can switch groups if they want. Using the shared whiteboard in gather. Town, participants map out the solution using different symbols (rectangle = material; triangle = meaning; circle = competence).	
20 min	Report Back 2	Reporters from each breakout group share their ideas. Other groups can ask questions.	
10 min	Wrap up	Thank participants for attending. Review next steps in the research process. Share survey link.	• Not applicable
Part B			
10 min	Opening	Participants sign into zoom. Introduction to study and land acknowledgement. Summary presentation of previous session.	• Not applicable
10 min	Bending elements icebreaker	Participants split into 4 pre-assigned breakout groups. In each group, participants introduce themselves and pose for their assigned element (earth, air, water, or fire).	• Not applicable
10 min	System traps		• Most votes:

(Continues)

(Continued)

Time	Activity	Description	Key findings
		Presentation about common system traps and opportunities. Participants vote in a poll to select their top choice of 5 solution ideas identified from the previous session. The 3 solution ideas with the most votes become the breakout groups for the next activity.	○ Bioplastic durable packaging reuse cooperative/sharing system ○ Single-use bioplastic ban ○ Extended producer responsibility (EPR) for bioplastics
30 min	Identifying traps	Participants join a breakout group of their choosing. Participants identify different failure points and the types of system traps that contribute to the failures and each trap is recorded on a sticky in Miro. Participants then identify opportunities to get out of the trap.	• Bioplastic durable packaging reuse cooperative/sharing system: ○ Traps: Low participation, small companies cannot afford to participate, dishes not returned, source materials and use of items have negative social/environmental consequences ○ Opportunities: Build on existing sustainability trends, create green jobs, small business incubators, regulation to prevent monopoly, collaboration for dish return, standardisation of dishes, regulation for environmental protection • Single-use bioplastic ban: ○ Traps: Policy backlash, does not solve root causes of plastic pollution, regulations not consistent and too many exceptions, alternative materials are unsustainable, small businesses affected more than large businesses, compromise food safety/longevity ○ Opportunities: Framing ban on environmental issues and social norms, maintain zero waste hierarchy in designing the ban, harmonise standards and regulations, life-cycle assessment on source materials, support local and small business innovation, ban only unnecessary single-use items • Extended producer responsibility (EPR) for bioplastics: ○ Traps: Program developed by a few stakeholders advancing their own interests, stakeholders throughout lifecycle are not connected, funds are misallocated/not collected fairly, low collection rates/system stays linear, does not address broader problem of plastic pollution ○ Opportunities: Structure program so funders do not control policies, communication feedback loop from waste management to manufacturers, variable fee structure governed by council at arms length from producers, broad collection system for all materials, product design/labelling to enhance recovery, integrate bioplastics into existing EPR programs
20 min	Group rotations	Facilitators and notetakers move to a different breakout group. The new breakout group reviews the traps and opportunities identified by the previous breakout group. Using new colours of sticky notes, they identify other traps and opportunities. After 10 minutes, rotate again.	
10 min	Break		
5 min	Business model canvas	Presentation about the business model canvas for thinking tangibly through a solution and mapping it out.	• Not applicable
50 min	Business model canvas breakouts	Participants join a breakout group of their choosing and can switch to a different group from the previous exercise if they wish. Facilitators present a summary of what other groups identified for traps and opportunities. Groups develop a pitch to convince a funder or decision maker to support their solution using the business model canvas as a tool in Miro.	• Reusable sharing food packaging program ○ Universal sharing system for a suite of container types ○ Reduce burden on businesses and consumers; standardised reusable wares provided as a service ○ Funded by food service businesses and small service fee by consumers • Single-use bioplastic ban on select bioplastics ○ Harmonised assessment framework for plastic product restriction program that includes bioplastics ○ Not an outright ban on all items, targeted to the most problematic ○ Co-developed with businesses and gradual transition to increase buy-in
25 min	SIMBIO Den	Each group has 2 minutes to do their pitch, followed by a 5-minute question period. Other participants can ask critical questions.	

(Continued)

Time	Activity	Description	Key findings
			○ Technical assistance to businesses for transition • Extended producer responsibility for bioplastics ○ Connect product design and end-of-life management ○ Funding stream from producers for developing, incentivising, and creating end-of-life processing solutions ○ Involve all stakeholders affected by bioplastics in setting direction of the program
10 min	Wrap up	Thank participants for attending. Review next steps in the research process. Share survey link.	• Not applicable

TABLE A6. Canada lab 3.

Time	Activity	Description	Key findings
Part A			
25 min	Opening and game set-up	Participants sign into Zoom. Introduction to study and land acknowledgement. Summary presentation of previous session. Introduction to the concept of serious games and the *Can You Sort It?* game.	• Not applicable
30 min	*Can You Sort It?* set-up	Participants split into 3 groups. In each group, participants have 5 minutes to sketch out their own ideas for labels to categorise plastics as compostable, biodegradable, recyclable, and other. Participants share what they have created and work together to come up with a "standard" that will be prototyped in the next session.	• Key themes in label design: ◦ Symbols which communicate the concept, like the Mobius loop for recycling, leaf for compost, trash can for disposal ◦ Colour scheme associated with different pathways, such as blue for recycling, green for compost, black for disposal • Considerations for label design: ◦ Biodegradable does not have a standard meaning ◦ Accessibility for visual impairments ◦ Different cultural contexts for symbols ◦ Visual identifier needed for reusables
5 min	Break		
5 min	*SIMBIOCity* intro	Introduction presentation to the *SIMBIOCity* game.	• Not applicable
45 min	*SIMBIOCity* set-up	Participants split into 3 groups for different locations (grocery store, mall food court, urban vegetable farm). Participants will need to design a system for selling different assigned products without using single-use plastics.	• Grocery store: ◦ Cheese sold as a whole wheel, in cloth, or reusable clamshell ◦ Crackers and cereals in standardised reusable glass or recycled aluminium containers in different sizes with QR codes for branding ◦ Reusable containers can be returned for deposit refund • Mall food court: ◦ Reusable and durable plastic wares for plates, utensils, cups, and takeout containers or customers bring their own (with clear rules to ensure hygiene) ◦ Deposit system with chips/barcodes to track items so they are returned ◦ Centralised dishwashing • Urban vegetable farm: ◦ Greens in linen or hemp mesh bags, reusable glass or plastic containers, or wrapped in local plant leaves ◦ Berries in cardboard baskets/egg cartons, reusable containers with lids, or reusable woven baskets lined with recycled paper ◦ Subscription model for repeat customers to exchange the same packaging ◦ Allow customers to fill own containers/packaging at markets
5 min	Wrap up	Thank participants for attending. Review next steps in the research process.	• Not applicable
Part B			
15 min	Opening	Participants sign into zoom. Introduction to study and land acknowledgement. Summary presentation of previous session.	• Not applicable
5 min	Kahoot! Practice	Introduction to Kahoot! Platform and a practice game with all participants to get to know the platform.	• Not applicable
25 min	*Can You Sort It?*	Participants split into 3 groups to play the game.	• 65% of items were correctly sorted • Challenges with sorting: ◦ Not having enough time (a few seconds) ◦ Difficulty seeing the symbols and colours

(Continued)

Time	Activity	Description	Key findings
			○ Paying attention to only the symbol, rather than the colour ○ Prior associations with the colours and symbols which conflicted with their meanings in the game
5 min	Break		
5 min	*SIMBIOCity* intro	Introduction on how to "play" *SIMBIOCity*. Each breakout group will get the design from a different group to evaluate.	• Not applicable
60 min	*SIMBIOCity*	Participants split into 3 groups. Facilitators narrate the design of another group as a story. Participants score the design on a scale of 1 to 5 based on criteria presented in the introduction to the activity and discuss the considerations in the scoring.	• Average scores: ○ Grocery store: 3.7 ○ Mall food court: 3.5 ○ Urban farm: 3.7 • Key discussion themes: ○ Standardisation/centralisation: Proposed changes would be more feasible if they occurred on a systems level, not just at individual locations. ○ Food safety: Concerns relating to food safety, but with the right system set up they could be mitigated. ○ Local systems: Single-use plastic ban presented exciting opportunities for more localised systems, products, and supply chains. ○ Environmental impact: Complexity of determining environmental impact, which would extend beyond the impacts of reducing single-use plastic waste. ○ Equity/inclusion: Risk that changes could disqualify people who are unable to participate in a deposit system or purchase and carry reusable items. ○ Bioplastics: Only used for specific applications, like on the distribution side/back end of the farmer's market, but not for mass consumption by the public, or developing products for reuse.
5 min	Wrap up	Thank participants for attending. Review next steps in the research process.	• Not applicable

TABLE A7. Poland lab 1.

Time	Activity	Description	Key findings
15 min	Opening	Participants sign into Microsoft teams. Introduction to study and the project	• Not applicable
30 min	Presentation	"Bioplastics through the prism of waste management" - speech the Institute of Circular Economy representative and SIMBIO stakeholder	• Providing the participants with knowledge in the field of compostable waste management and the possibilities of composting bioplastic packaging
30 min	Presentation	Diagnosis of challenges for the use of bioplastic packaging in the light of the report on the implementation of the first stage of the SIMBIO project	• A summary of the results of the first stage of the project, as the starting point for lab 1. • There are four key problems regarding the development of bioplastic packaging in Poland: 1.Insignificant share of bioplastic packaging in the food packaging market in Poland 2. Low awareness and the willingness of consumers to buy food products in bio-packaging 3. Insufficient social and environmental responsibility of enterprises in the supply chains of food packaging for the benefit of the circular economy 4. The low level of development of the compostable packaging waste management
15 min	Q&A	Comments, questions and answers session	• Not applicable
10 min	Introduction	The purpose and assumptions of the dialogue and cooperation of stakeholders during discussion panels"	• Not applicable
10 min	Break	Participants split into 3 pre-assigned breakout groups	• Not applicable
90 min	Group timelines	In each group, participants introduce themselves by name and organisation. A facilitator leads each group discussion "analysis of barriers and identification of their causes as key challenges for the development of the bio-packaging market in Poland".	• Completing Ishikava diagrams for each of the four problems. • Barriers to market development under problem I: 1. High market prices of compostable packaging in relation to the prices of conventional plastic packaging 2. Limited properties of bio-packaging in relation to conventional plastic packaging 3. A lack of support to level the playing field for compostable packaging • Barriers to market development under problem II: 1. An insufficient level of consumer knowledge about bio-packaging in the circular economy 2. A low social commitment to circular waste management 3. The poorly developed infrastructure supporting the selective collection of packaging by consumers 4. Greenwashing in the food bio-packaging market (from the consumer perspective) • Barriers to market development under problem III: 1. Insufficient integration of economic, environmental, and social goals into one main sustainable goal 2. A lack of the link between investor assessment and corporate sustainability, including the approach to managing packaging in an environmentally responsible manner 3. A lack of sufficient cooperation of enterprises for the benefit of circular economy in the field of, i.a., design, and development of the food bio-packaging, including compostable packaging 4. A lack of social pressure on the implementation of environmentally and socially responsible activities by enterprises 5. Greenwashing in the food bio-packaging market (from the perspective of companies) • Barriers to market development under problem IV: 1. Lack of uniform and transparent regulations regarding the planning and organisation of the closed-loop compostable packaging 2. Insufficient communication between the private and public sectors on how to increase the use of compostable food packaging 3. Poorly developed compostable waste management system 4. Lack of sufficient financial incentives to support activities

(Continued)

Time	Activity	Description	Key findings
			for the benefit of the circular economy of compostable packaging at the level of local government units • 16 causes of barriers were identified for problem I, 23 causes of barriers were identified for problem II, 39 causes of barriers were identified for problem III, 25 causes of barriers were identified for problem IV
10 min	Break		• Not applicable
30 min	Report Back	Facilitators share conclusions of their breakout groups with the whole group	• Presentation of four Ishikawa diagrams to all participants.
5 min	Wrap up	Thank participants for attending. Review next steps in the research process.	• Not applicable

TABLE A8. Poland lab 2.

Time	Activity	Description	Key findings
15 min	Opening	Participants sign into Microsoft teams. Introduction to study and the project's third stage	• Not applicable
30 min	Presentation	"Diagnosis of the problems and barriers to the development of the food bio-packaging market in Poland "– In the light of the report of the second stage of the SIMBIO project	• A summary of the results of the second stage of the project, as the starting point for lab 2.
30 min	Presentation	"Composite materials with a biodegradability trigger - a case study" – a speech by a professor from another university in the same city	• Providing the participants with knowledge in the field of innovations in packaging materials.
30 min	Presentation	„government approaches to bioplastics Management in Canada" –a speech by the research associate within the SIMBIO project from Canada	• Providing the participants with knowledge in the field of legislative conditions for the development of the bioplastics market in Canada
25 min	Q&A	Comments, questions and answers session	• Not applicable
10 min	Introduction	The purpose and assumptions of the dialogue and cooperation of stakeholders during discussion panels	• Not applicable
15 min	Break	Participants split into 3 pre-assigned breakout groups	• Not applicable
95 min	Group timelines	In each group, participants introduce themselves by name and organisation. A facilitator leads each group discussion "solutions for managing supply chains and the life cycle of bio-packaging for food in accordance with the principles of circular economy".	• A survey questionnaire was prepared with the aim to discover the most important problems and barriers along with their causes for the development of the bio-packaging market, according to the stakeholders. The results were the subject of discussion panels during Lab2. • The key barrier to the problem of insignificant share of bio-packaging, including compostable packaging, in the food packaging market in Poland, is the high price of bio-packaging in relation to the price of the packaging made of plastics. The main reasons for this barrier are: 1. The high prices of raw materials, the low availability of imported and domestic raw materials to produce bio-packaging, the high logistics costs related to the import of raw materials 2. The low demand for bio-packaging (resulting from low environmental awareness of consumers and difficulties in identifying such packaging). Panel participants indicated 10 different solutions that could help eliminate the barrier and its causes. However, the most urgent solution identified during the panel was an increase in the number of production plants (producing bioplastics) in Poland and improving their cooperation with organisations performing R&D projects. • The key barrier related to the problem of the low awareness and willingness of consumers to buy food products in bio-packaging, is the insufficient level of consumer knowledge about bio-packaging (including compostable ones) in a circular economy. The main reasons for this barrier are: 1. The lack of consumer awareness of the importance of the packaging problem, the lack of education (e.g. in schools, social media), information campaigns on bio-packaging (including compostable packaging), and the shortage of mobile applications supporting the dissemination of knowledge and waste segregation 2. The lack of clear information on the packaging about its compostability. Panel participants indicated 4 different solutions that could help eliminate the barrier and its causes. According to the participants, the most urgent and the most difficult solution to implement is the inclusion of uniform information on the compostability placed on the packaging. The information serves to educate the consumer about the packaging and how to manage the packaging waste. • The key barrier related to the problem of insufficient social and environmental responsibility of enterprises in

(Continued)

Time	Activity	Description	Key findings
			the supply chains of food packaging, is the lack of sufficient cooperation of enterprises for the benefit of the circular economy. The main reason for this barrier is 1. The lack of cooperation between enterprises in the field of acquiring and gathering knowledge about bio-packaging and the circular economy, the lack of joint R&D works for bio-packaging, no economies of scale, no joint actions to simplify and standardise the specifications of bio-packaging, the lack of sufficient cooperation for a uniform European standard and the lack of interdisciplinary cooperation within enterprises. Panel participants indicated 29 different solutions that could help eliminate the barrier and its causes. However, the most urgent solution identified during the panel was designing a strategy for the development of the bio-packaging market (including compostable packaging), i.e. an 'umbrella' for the activities of internal stakeholders of supply chains, is extremely urgent and difficult to implement. • The key barrier related to the problem of the low level of development of compostable packaging waste management, is the lack of uniform and transparent regulations regarding the planning and organisation of closed-loop compostable packaging. The main reasons for this barrier are: 1. The legal regulations that are inadequate and insufficient for the market, often also inconsistent, and above all (especially in recent years) changing legal regulations 2. The limited awareness of the implementation of the circular economy idea. Panel participants indicated 10 different solutions that could help eliminate the barrier and its causes. The panel discussion led to the definition of the two most urgent solutions. The first is the development of a strategy for the compostable packaging market along with operational documents. The second solution is establishing an association of processors of bioplastics (and/or producers of compostable packaging) obtained from biodegradable renewable raw materials.
20 min	Report Back	Facilitators share conclusions of their breakout groups with the whole group	• Presentation of the lists of solutions (aimed at solving four problems by eliminating key barriers and their main causes) to all participants.
5 min	Wrap up	Thank participants for attending. Review next steps in the research process.	• Not applicable

TABLE A9. Poland lab 3.

Time	Activity	Description	Key findings
10 min	Opening	Participants sign into Microsoft teams. Introduction to study and the project's fourth stage	• Not applicable
20 min	Presentation	"Identification of potential solutions to the problems and barriers to the development of the food bio-packaging market in Poland "– Summary of results included in the report of the third stage of the SIMBIO project	• A summary of the results of the third stage of the project, as the starting point for lab 3.
30 min	Presentation	"Best practice in food waste collections. The case study of Italy" – a presentation delivered by the representative of the Bio-based and Biodegradable Industries Association (BBIA) and the European Circular Bioeconomy Policy Initiative (ECBPI)	• Familiarising participants with knowledge in the field of organic recycling within the circular economy and food waste collection in Italy.
20 min	Presentation	"Eco-designing packaging for organic and material recyclability" –a presentation delivered by the representative of Institute of Biopolymers and Chemical Fibres from Poland	• Providing the participants with knowledge in the field of eco-design challenges related to bio-based packaging.
20 min	Presentation	"Packaging - standardisation in practice" – a presentation delivered by the representative of polish Committee for Standardization	• Providing the participants with knowledge in the field of standards of packaging biodegradability and the packaging standardisation process.
15 min	Q&A	Comments, questions and answers session	• Not applicable
15 min	Break	Participants split into 3 pre-assigned breakout groups	• Not applicable
10 min	Introduction	"Purpose and assumptions of the dialogue and cooperation of stakeholders during the discussion panels" – Introduction to group work	• Not applicable
60 min	Group timelines	Participants introduce themselves by name and organisation. A facilitator leads group discussion "designing a strategy for the development of the compostable packaging market".	• A national strategy can play a key role both to stabilise the conditions and to dynamise the development of the compostable packaging market at each macro (central government administration) level, meso- (regional and local government administration) and microeconomic (businesses and consumers). • The strategy should provide a coherent and integrated vision and key strategic goals defined which support the creation of the ecosystem of external and internal stakeholders of a compostable packaging supply chain, who perform their own activities and cooperate in the circular economy.
35 min	Group timelines	A facilitator leads group discussion "establishing an industrial organisation for stakeholders in bio-packaging supply chains". (carried out at a later date)	• The industry organisation should be aimed at a wide range of stakeholders representing the links of the compostable food packaging supply chains, including suppliers of raw materials and bioplastics, packaging producers, packaging distributors, waste management operators, business customers as well as research institutions. • The main roles of the industry organisation are as follows: The integration and collaboration of stakeholders in the compostable packaging market, the exchange of knowledge and experience as well as the elimination of barriers limiting the development of the compostable packaging market, the creation of a strong entity working for the benefit of all parties involved, through representative, educational, research and lobbying functions. It also aims to achieve added value through trust-based cooperation in a network of various stakeholders, becoming an impetus to accelerate the development of the compostable packaging market.
35 min	Group timelines	A facilitator leads group discussion "developing a technological platform for stakeholder cooperation in bio-packaging supply chains". (carried out at a later date)	• The role of a digital multi-sided business-to-business (B2B) platform for the development of the compostable packaging market is diverse. Firstly, it can facilitate the interaction and exchange of goods or services between

(Continued)

Time	Activity	Description	Key findings
			two or more groups of participants. Secondly, the platform is for support coordination and the improvement of material flows, information and financial as well as business relationships and processes management. Thirdly, the technology platform can also be perceived as the foundation of innovative activity in creating new, complementary services and products. Moreover, the role of technology platforms is seen as crucial in stimulating, creating and sustaining a successful innovation ecosystem that supports information and communication flows between supply chain participants. • Synergic results from the collaboration of different organisations are achieved especially on digital multilateral platforms B2B that gather companies in one place - supply chain participants with diverse scopes and goals of activities.
15 min	Report Back	Facilitators share conclusions of their breakout groups with the whole group	• Presentation of key assumptions for developing a national strategy, establishing an industry organisation and a technological platform for stakeholder cooperation to all participants.
5 min	Wrap up	Thank participants for attending and discuss the next steps in the research process.	• Not applicable

TABLE A10. UK lab 1.

Time	Activity	Description	Key findings
30 min	Soundcheck	Participants sign into Zoom, and soundcheck.	• Not applicable
10 min	Welcome and introduction	Introduction to study and the project (Coventry University representative)	• Not applicable
10 min	Presentation	Perspectives: Future of bioplastic industry (BBIA representative)	• Not applicable
15 min	Presentation	What do we know about bioplastic packaging systems so far? (Coventry University representative)	• Not applicable
10 min	Presentation	Perspectives: Exploring barriers and opportunities for relevant industrial compostable plastic waste (Association for Renewable Energy and Clean Technology [REA] representative)	• Not applicable
10 min	Instruction and guidance	Instruction and guidance next step (Miro instructions) (Coventry University representative)	• Not applicable
65 min	Breakout groups	Participants split into 3 pre-assigned breakout groups (production, consumption, waste management). Facilitated discussion groups in parallel sessions.	• Not applicable
10 min	Break		
30 min	Report Back	Facilitators share the conclusions of their breakout groups with the whole group.	• Key challenges/barriers:: ○ Need for improved certification standards for industrial composting, AD, and waste management procedures. ○ Bioplastic materials developed without consideration of how waste management can process them. ○ Consumers doubted their ability to separate out bioplastic packaging in waste collection streams despite eco-friendly labels being used. ○ Infrastructure's role in waste management: Concerns about the biodegradability of current compostable food waste caddies available to consumers and the implications for packaging made of bioplastics. • Key opportunities: ○ Develop clearly defined and legally binding labels for compostable products. ○ Develop guidelines for waste management (WM) industry to process compostable plastics. ○ Provide certainty about producers' claims regarding their products by enforcing current certification standards. ○ Improve compatibility of industrial certification standards with label and WM procedures. ○ Provide and develop clear and consistent terminology to avoid confusion; for instance, for industrially compostable plastics or home compostable plastics. ○ Develop educational programmes for home composting products. ○ Replace the material made for hard-to-recycle applications with compostable materials.. ○ Develop industrial infrastructure for disposing of compostable materials, such as a composting and AD plant. ○ Improve research and development of other feedstocks. ○ Adopt consistent policies to support the use of compostable plastics.
5 min	Wrap up	Discuss the next steps in the research process and thank participants for attending.	• Not applicable

TABLE A11. UK lab 2.

Time	Activity	Description	Key findings
30 min	Soundcheck	Participants sign into Zoom, soundcheck.	• Not applicable
5 min	Welcome and starting points	Update of the study (Coventry University representative).	• Not applicable
15 min	Presentation	Perspectives: The compostable materials certification scheme (stakeholder engagement compostable materials – REAL).	• Not applicable
15 min	Presentation	Perspectives: Regulatory (certifications) and consumers' perspectives (garden organics bioplastics representative).	• Not applicable
30 min	Activity	Embracing possibilities and consumer perspectives	• Solution themes (bolded items for next activity): ○ **Communication with the consumers** ○ Educational programmes ○ **Certification standards and guidelines** ○ Specific products and more feedstocks ○ **End of life** ○ Policies
30 min	Breakout groups	Participants split into 5 pre-assigned breakout groups to explore the design of the solutions. Facilitated discussion groups in parallel sessions.	• Not applicable
20 min	Report Back	Facilitators share the conclusions of their breakout groups with the whole group (designing solutions).	• Communication with the consumers ○ Reduce message complexity to achieve clear and consistent communication. Bioplastics are available in a variety of types (e.g. fossil-based plastics that can biodegrade, biobased [or partially biobased] and non-biodegradable; and biobased and biodegradable plastics), and they have a similar appearance to conventional plastics.. • Identify how and where to dispose of compostable plastics. • Create appropriate eco-labels for packaging, making it easier for consumers to understand. • Certification standards and guidelines ○ Develop regulatory tools, such as certification standards and guidelines for waste management, with the aim of supporting a sustainable packaging system. • End of life ○ Develop home composting, industrial composting, AD or dual processing (AD and composting) as possible end-of-life routes. ○ Increase the evidence that compostable plastic can be degraded by home composting.
5 min	Wrap up	Discuss the next steps in the research process and thank participants for attending.	• Not applicable

TABLE A12. UK lab 3.

Time	Activity	Description	Key findings
30 min	Soundcheck Reception	Participants sign into Zoom and soundcheck. Participants are welcome at techno Centre (Coventry University) and online)	• Not applicable
10 min	Welcome and introduction	Update of the study (Coventry University representatives)	• Not applicable
10 min	Presentation	Perspectives: When did we stop thinking! (plastic manufacturer representative)	• Not applicable
10 min	Presentation	Perspectives: Communication with consumers (BBIA representative)	• Not applicable
10 min	Presentation	Perspectives: Importance of labelling – What consumers want (the on-pack recycling label [OPRL] representative)	• Not applicable
10 min	Presentation	Perspectives: End of life: AD perspective. Anaerobic Digestion and Bioresources Association representative (ADBA)	• Not applicable
10 min	Presentation	Perspectives: Together, we can (Waste and Resources Action Programme [WRAP] the UK Plastic Pact representative)	• Not applicable
10 min	Presentation	Perspectives: Compostable plastics: Unlocking existing barriers to systems change (University College London [UCL] academic representative)	• Not applicable
10 min	Presentation	Perspectives: No clue about bioplastics (Vrije Universiteit Amsterdam academic representative)	• Not applicable
10 min	Presentation	Perspectives: Policies to move forward the bioplastics agenda (bioladies network representative)	• Not applicable
20 min	Q&A		• Not applicable
10 min	Break		• Not applicable
40 min	Break-out rooms	Participants split into 6 pre-assigned breakout groups to explore the prototype of the solutions (certification standards & guidelines, end-of-life, policies, specific products, education and communication) in terms of feasibility (main positive or negative factors to take into account for the implementation of these solutions), practicality and impact. Facilitated discussion groups in parallel sessions.	• Not applicable
20 min	Report Back	Facilitators share the conclusions of their breakout groups with the whole group.	• Certification standards & guidelines ○ Feasibility (feasible, but requires) • Technical competence. • Wider accountability. ○ Practicality (practically possible, but depends on) • Uptake of the measures and how stringent the standards are in comparison to current industry practices. • Desire for certification standards by the wider industry and the perceived benefits. • End of life ○ Feasibility (feasible, but requires) • End-of-life investment. • Address the risk of contamination of waste streams. ○ Practicality (practically possible, but depends on) • Contamination of the digestate • Greater investment • Policies ○ Feasibility (feasible, but requires) • Producer responsibility and place tax incentives to encourage recycling.

(Continued)

Time	Activity	Description	Key findings
			• Address specific changes needed across the sector (such as an increase in investment in industrial composting). ○ Practicality (practically possible, but depends on) • Cost of compostable over fossil fuel-based plastic materials • Policy alignment with the circular economy • Specific products ○ Feasibility (feasible, but requires) • Use experience from existing biobased biodegradable plastics. • Producers and brands to redevelop into BBPP. Reluctancy after investing in recyclability innovation. • Unified driver for compostable plastic be the most appropriate sustainability pathway. ○ Practicality (practically possible, but depends on) • Waste management systems. • Address the high cost of developing and purchasing compostable materials.
60 min	Lunch		• Not applicable
120 min	Scenario SIMBIO game	Prototyping solutions with the scenario SIMBIO game for three bio-based biodegradable plastic packaging products closer to the market, such as compostable ready meal trays, coffee pods and food caddy liners.	A sustainable path for these products, can be facilitated by: • The implementation of certifications with a specific timeframe over which high degradability standards can be met. • Collaboration between brands and retailers to help implement closed-loop recycling systems, which are accessible to consumers and thus may have a significant impact on consumer behaviour. • Collaboration between stakeholders involved in the commercialisation of packaging products and waste management, including collection, sorting, and recycling of household food waste, aiming at improving the processing of the end-of-life of compostable packaging. • Assisting behaviour change by providing consumers with better information about the differences between conventional & conventional plastics and providing innovations that act as "bridge technologies" (e.g. bio-paper caddy liners made of cellulose or biopolymers), so they can distinguish between them easily. By introducing these bridge technologies faster on the market, consumers' behaviour may change and certification standards and waste management processes may evolve to include a wider spectrum of materials. Challenges: • Rising inflation and production costs across industries are a barrier to investment in the development of new biobased biodegradable materials, with consumers wary of price increases. • Products with a clear closed-loop recycling arrangement would prevail.
5 min	Wrap up	Discuss the next steps in the research process and thank participants for attending.	• Not applicable