UNIVERSITY OF HULL

An investigation into practices and determinants of the circular economy in the food by-product management using multiple case research design

being a thesis submitted in partial fulfilment of the

requirements for the degree of

Doctor of

Philosophy

in the University of Hull

by

Nhu Quynh Do MSc

June 2022

Declaration

I do declare and state the following about this thesis:

1. That I have presented this PhD thesis as my own original work and I have not submitted this work elsewhere in fulfilment of this or any other award.

2. That I have duly acknowledged where the work of others has been used in any way.

3. That it is intended the copyright of this thesis remains with the author as such the use of this work is permitted provided that full acknowledgement is made.

4. That my thesis consists of 79,965 words (excluding bibliography).

Acknowledgements

My PhD accomplishment is surely due to generosity and support from many people. I would like to humbly express my gratitude and appreciation for their presence throughout my PhD journey.

I am grateful to my supervisors, Prof. Amar Ramudhin and Professor. Nishikant Mishra, for all support, inspiration and encouragement as well as constructive feedback that they have given me. It is my privilege to have worked under their supervision over the past four years of my PhD journey. Prof. Ramudhin has put me in contact with the industrial and academic partners through the GOLF project (Project 777742: EC H2020-MSCA-RISE-2017) and allowed me to travel multiple times to different countries to widen my hands-on knowledge. Had it not been for these fantastic experiences, I would not have had to collaborate and learn from highly talented colleagues from different Universities such as Wageningen University and the University of Liverpool and collect the data from multiple firms that serve the purpose of my research. Prof. Ramudhin is also a visionary leader and a great source of inspiration for any research students in the academic arena. Hence, I am honoured to know and work under his guidance and mentoring for four years. Equally, I owed an enormous debt to Prof. Mishra. Prof. Mishra has introduced me to a proper way of conducting qualitative research method and patiently arose my interest in conducting the research using this method. Prof. Mishra also provided me with high-quality materials for reference to significantly upgrade my writing and researching skills. Without his guidance and strategic direction, I would not have been able to finish my PhD thesis and publish the peer-reviewed articles in the leading journals in my field. Furthermore, during the challenging period as a result of the COVID-19 pandemic, I feel extremely lucky to receive emotional support from Prof. Mishra. This thesis is as much his as mine, and I am thankful that I had a chance to know work with and learn from him.

In addition, I would like to express my heartfelt gratitude and appreciation to my previous supervisor, Dr Alessandro Creazza for his guidance in the first two years of my PhD. He has shown me the importance of conducting a thorough literature review using the systematic method. Dr Creazza has unwearyingly read my research multiple times and given me thorough feedback and constructive criticisms to improve the quality of my research. Even after he was no longer my PhD supervisor, Dr Creazza has never failed to provide me with timely and generous support. I am so grateful that we are still in contact and continue to work on collaborative projects.

Many thanks also go to all participants in my PhD study for enthusiastically expressing their interest in my study and engaging in the interviews to share their valuable knowledge and expertise, as well as enabling me to gather in-depth qualitative data in order to fulfil the purpose of the study.

Next, I offer my sincere appreciation to Hull University Graduate School for awarding me a scholarship and HUBS research office staff for the administrative and moral support throughout the process, particularly during the COVID-19 period.

Finally, my heart goes to my family in Vietnam and friends at the University of Hull. Their love and trust have inspired me to keep going with my research, maintaining my sanity and interests in research and optimism. Your encouragement is much appreciated and duly noted.

Abstract

Food waste is one of the biggest global challenges in our modern time due to its serious environmental, economic, social and ethical implications. There is a pressing concern to address this challenge globally, which prompts governments, industries and academia alike to rethink the food system and take actions to reduce and manage the waste issues effectively. A circular economy that drifts away from the linear take-make-dispose model is touted as a practical solution to not only enable dual goals of wealth generation and GHG mitigation but also radically transform the way we look at and manage food waste. However, little is known about how the circular economy can be properly translated and executed in food by-product valorisation. This is intensified by a lack of genuine interest from practitioners as a result of enormous and systemic changes required in the circular economy concept. The practitioners are still struggling to grasp a consistent understanding of the concept for onward implementation. Coupled with a response to calls to move the attention to food by-product management, this study was undertaken to understand the nature of the circular transition with the view to shed light on its implementations in the food by-product management and the associated determinants along the transition process in the UK context.

For the explorative purpose, a multiple case study research method following an abductive qualitative research approach was adopted. The last decade has witnessed interesting dynamics in food by-product management in the UK. For example, anaerobic digestions continue to take off in volume and efficiency, yet other types of innovations continue to exhibit in the valorisation of the food by-products. Therefore, six cases of small and medium-sized food by-product processors were theoretically sampled to elucidate these innovative efforts. The cases have direct involvement in processing food by-products in the UK. This enabled the researcher to explore and gain insights into the phenomenon of circular innovations in the contemporary context of food waste management. Data were collected by semi-structured interviews, triangulated with evidence from other sources, including observations from site visits and exclusively accessed and publicly available documents.

The findings yielded critical themes concerning three research questions. The circular practice specifies the types of innovation practices employed in each case that centre on the operations and technologies, by-product procurement, output products and their markets. A list of 11 drivers and 13 barriers is yielded and aggregated into six themes, regulatory, social, cognitive, economic, supply chain, and technological sources. Interestingly, the technological factor is not listed in the list of drivers. The nexus of circular practices, drivers and barriers is then elaborated on the theoretical anchor of an integrated institutional theory with an institutional logic add-on. Overall, the finding indicates that weak momentum for the circular engagement is due to deep uncertainty perceived in such engagement. Finally, theoretical, methodological and practical contributions are discerned while future research directions are suggested.

List of original publications

The works mentioned below were published prior to the viva date of this thesis but originated from the pursuit of this thesis. Hence, some sections of this thesis, though not citing these works, may appear verbatim from these published works.

JOURNAL ARTICLE LIST

Do, Q., Ramudhin, A., Colicchia, C., Creazza, A., & Li, D. (2021), "A systematic review of research on food loss and waste prevention and management for the circular economy", *International Journal of Production Economics*, Vol. 239, pp. 108209. doi: https://doi.org/10.1016/j.ijpe.2021.108209

Do, Q., Mishra, N., Ramudhin, A., Colicchia, C., Creazza, A., Ramudhin, A. (2021), “An extended institutional theory perspective on circular economy adoption: practices and determinants in the seafood by-product management in a developing country”, *International Journal of Production Economics*, 247, p. 108400. doi: https://doi.org/10.1016/j.ijpe.2021.108400

CONFERENCE AND OTHER ACADEMIC WORKS

Do, Q., Ramudhin, A., Mishra, N., Lalwani, C., Li, D. (2019), “A Systematic Review of food waste management for the Circular Economy”, International Symposium on Logistics Conference 2019, Germany.

Do, Q., Ramudhin, A., Nguyen, DXC. (2019), “Food waste identification and mitigation in multi-tier food supply chains in Vietnam”, International Symposium on Logistics Conference 2019, Germany.

Green Port Impact Assessment Report (2018), Chapter 2: Methodology, pp. 11-20 and Chapter 5: Siemens Gamesa Supply Chain Mapping pp. 209-221.

Contents

List of Figures

List of Tables

Abbreviations

AD	Anaerobic Digestion
B2B	Business to Business
B2C	Business to Consumer
BBSRC	Biotechnology and Biological Sciences Research Council
C&G	Collagen and gelatine
CSR	Corporate Social Responsibility
EAE	Enzyme Assisted Extraction
FAO	The Food and Agriculture Organization of the United Nations
FLW	Food loss and waste
FSC	Food supply chain
GHG	Greenhouse gas
HARP	Heightening Awareness of Research Philosophy
HHPE	High Hydrostatic Pressure Extraction
MAE	Microwave-Assisted Extraction
MDF	Medium-density fibreboard
NIBB	Network in Industrial Biology and Biotechnology
PLE	Pressurized Liquid Extraction
PUFAs	polyunsaturated fatty acids
3Rs	Reducing, reusing and recycling
RQ	Research question
SALSA	Safe and local supplier approval
SCG	Spent coffee grounds
SCM	supply chain management
SCT	Social capital theory
SDG	Sustainable Development Goal
SFE CO2	Supercritical Fluid Extraction with CO2
SME	Small and Medium Enterprise
SSCM	Sustainable Supply Chain Management
SWE	Subcritical Fluid Extraction with water
UAE	Ultrasound Assisted Extraction
VRIN	Valuable, rare, inimitable and non-substitutable
WFD	Waste Framework Directive
WRAP	Waste & Resources Action Programme

Chapter 1 Introduction

This thesis explores the management of food by-products under the circular economy transition in the UK. Specifically, the research delineates how food supply chain actors innovatively operationalise the circular economy in the management of by-products and discerns the poorly understood factors driving and hindering these operations. The introduction chapter firstly offers the rationale for the research from a personal perspective (Section 1.1), followed by the overall context where the research problem is derived (Section 1.2). To address the research problem, the research question and objectives are specified next (Section 1.3). Section 1.4 delineates a clear boundary in the scope of this thesis before the thesis structure is outlined in Section 1.5.

1.1 Research motivation

This section reflects upon my personal motivation to pursue PhD research in the interplay of two topics, the circular economy and food waste management, followed by the motivation to select investigation contexts in the UK.

During my master's degree at the University of Hull, I became fascinated by the academic research in the sustainable supply chain management field. My working experience in higher education in Vietnam further reinforced my desire to apply for a postgraduate study with an expectation of advancing my research skills and knowledge in a particular area under the overarching supply chain discipline. My expectation materialised when I got accepted to study PhD at the University of Hull, and this is when my concrete research idea – an interface between circular economy and food supply chain management – came to light. While I followed the progress in the food supply chain (FSC) area with curious interest, the question of how the emergent phenomenon – a circular economy – could be translated to be a more sustainable food system was intriguing. This question was the starting point of my research progress. The initial question was later refined to consider a landscape that involves the actual firms to unpack the circular economy opportunity to solve the food waste issues, a key puzzle in building a sustainable food system. I was galvanised to explore the mechanisms through which the circular economy can lead to better food waste management and why the mechanisms have not been widespread in practice. Further, I was personally fascinated by the homogeneous flow of wastes discharged from FSC, so I narrowed down the scope of the investigation to the exploration of food by-product management under the circular economy landscape.

My educational background and working experience arouse my interest in the choice of the investigation context in the UK. The UK is the country where my postgraduate degree takes place. During this time, I have been given the chance to work with and listen to the perceptive experience of the stakeholders in the FSC. When the UK policy gives way to more trendy businesses such as the wind energy sector, the recent COVID-19 pandemic event is a wake-up call for considering a local and more resilient food system. In this context, a better valorisation of food waste offers a promising solution. Besides, the UK represents a developed country where the food waste management issue is pressing. This is therefore captivating to explore how and in which ways food waste can be better managed and which factors initiate and hinder them from the realities of one developed country. Apart from my personal motivation, this research idea and motivations are also aroused from the literature standpoint, which will be provided in the following section.

1.2 Research context and problem

This section explains why the operationalisation of the circular economy in food by-product management appears to be a significant lacuna in extant literature that needs to be explored. Section 1.2.1 accentuates the food waste management issue in broad FSC literature. Next, Section 1.2.2 offers a theoretical solution for this problem from the circular economy standpoint, before raising critical concerns that are premises for this research.

1.2.1 Food waste management in the food supply chain

A FSC refers to a series of processes, operations and entities from farm to fork (Bourlakis and Weightman, 2004; Dani, 2015). The processes and operations include production, processing, distribution, logistics, consumption and disposal. Entities that involve in a generic FSC consist of food producers, processors, traders, retailers and wholesalers, catering services, and logistics companies. Logistics companies are responsible for moving and/or storing foods throughout the chain. Unlike the other supply chain, FSC is characterised by seasonality, high demand/supply volatility, and regionality. FSC can be divided into the commodity chain and producer chain where the former targets the end-users such as fresh fruits and vegetables while the latter aims at a bulk sale of raw materials to the processing plants. One of the important disciplines in FSC management that has received an increasing research interest in recent years is the management of food waste.

Food waste management has been in the spotlight for its catastrophic implications. A third of the annual food produced for human consumption (roughly 1.3 billion tons) is either wasted or lost along the FSC (FAO, 2011; 2014). Food waste accounts for 24% of freshwater use, 28% of total global cropland area, 23% of global fertiliser use (Kummu *et al.*, 2012) and about 8% (3.3 billion tonnes of CO_2 equivalent) of total greenhouse gas (GHG) emission (FAO, 2014). Halving the amount of food waste contributes to reducing GHG emissions from food-sourced by about 20-30% (Bajželj *et al.*, 2014). While about 10.7% of the world population (nearly 815 million) is undernourished (FAO *et al.*, 2018) and 9.6 billion people need to be adequately fed by 2050 (United Nations, 2017), wasting foods represents a contemporary economic, environmental, social and ethical challenge at a global scale, which requires urgent political and practitioners' attention to combat this global issue (FAO, 2013; Papargyropoulou *et al.*, 2014; Searchinger *et al.*, 2019; Teigiserova *et al.*, 2020).

1.2.2 Food waste management under the circular economy

One of the novel pathways to prevent and manage food waste is the adoption of the circular economy ideology that has been supported in the EU political agenda (European Commission, 2015). In essence, a circular economy is a restorative and regenerative system in which the concept of waste does not exist and both materials and resources are kept in closed loops for multiple—ideally infinite—times to maximise the value retained from resources (Ellen MacArthur Foundation, 2012). Food waste prevention is identified as the top priority and an integral part of an EU Action Plan for its transition towards the circular economy. The Circular Economy Action Plan not only put forward a series of actions to promote more sustainable production and consumption behaviours and patterns in the EU food system, e.g. food donation and labelling awareness but also fosters the adoption of biotechnologies and practices to convert food waste into a variety of valuable bio-based products for long-term socio-economic and environmental benefits (Maina *et al.*, 2017; Zabaniotou and Kamaterou, 2019). In the Action Plan, a common EU methodology for food waste quantification is also proposed to ensure the consistent quantification, monitoring, and analysis of food waste statistics. These measures support the EU on its trajectory in meeting the United Nations' Sustainable Development Goal (SDG 12.3) "*by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses*" (Flanagan *et al.*, 2018). Aligned with the surge in political backing, food waste management emerges as a salient theme in the circular economy-related academic discourse with exponential growth in the publications over the last five years (Kyriakopoulos *et al.*, 2019).

However, the circular economy is often described as an underspecified concept that is difficult to comprehend (de Jesus and Mendonça, 2018), which causes difficulties for practitioners and scholars to translate its subtle ideology into specific realms such as the management of food waste including by-products. Some scholars equate food waste management under the circular economy with conventional food waste management such as the one proposed in the waste hierarchy while others constrain the circular economy to a 'recycling economy' – an interim arrangement between linear and circular economy (Webster, 2021). It is not apparent in literature how the management of food waste and by-products can be different under the circular economy landscape. Meanwhile, some underlying concepts are often overlooked such as a cascading use that advocates the sequential reuse of the remaining resources from previously used commodities and substances. To the researcher's best knowledge, the question of how the circular economy is applied in the management of food by-products appears largely underexplored. This is further elaborated in-depth in Chapter 2 of this thesis.

In addition, while a large body of literature has shown the potential benefits of a circular economy transition, practical evidence about how practitioners employ the circular economy and achieve better food by-product valorisations appears to be rare (Ghisellini *et al.*, 2016; Agyemang *et al.*, 2019). This can be attributable to numerous challenges and uncertainties associated with the commercialisation phase of the novel circular food by-product management. It is imperative to discern these challenges as well as the drivers for these rare attempts that can be leveraged to overcome these challenges for a smoother circular transition. Hence, real-world case studies in different settings are critical to demonstrate the feasibility of and associated influencers on the operationalisation of the circular economy in food by-product management and thereby advancing the global transition toward a circular economy.

This thesis shed light on these problems by expounding on how the by-products are innovatively managed in the FSC under the circular economy transition using empirical evidence. At the same time, the mechanism to induce these innovations and barriers needed to be mitigated are considered to diffuse these practices to the mainstream. This is also a response to a recent call in the review paper of Govindan and Hasanagic (2018) for future exploratory research into the nexus of three critical components – key practices for implementing the circular economy, drivers for fostering their adoption, and key barriers to be eradicated– that focuses on the supply chain level.

1.3 Research questions and research objectives

As well-framed in the preceding section, the study attempts to provide a reality check for the achievement of the circular economy in food by-product management while supplementing empirical evidence for exploring the nexus of practices, drivers and barriers. Specifically, it provides insights into three following research questions (RQ):

(1) RQ1: How have circular economy practices been adopted into the management of food by-products?

RQ1 explores how the practitioners in the FSC currently interpret the circular economy and select the choice for food by-product management differently from the conventional by-product management. Undoubtedly, the perception of the circular economy concept influences the engagement decision which is the circular economy practice that is central to this thesis.

(2) RQ2: Why are firms being driven to be engaged in the circular practices in food by-product management?

RQ2 delves into the driving forces behind the engagement of each case. While the circular economy adoption in food by-product management remains novel with the presence of unknown unknowns, it is interesting to investigate why some firms decided to go down this route without clear financial stimulation. Insights into these drivers from industrial perspectives open up the opportunities to encourage future engagement and thereby contributing to the transition towards the circular economy.

(3) RQ3: Why does their engagement in the circular practices in the food by-product management being derailed or hindered?

RQ3 aims to discover barriers perceived by stakeholders in each case's engagement process, which provides the reasons for the rare examples of these circular by-product management adoptions in the UK context. It is imperative to acknowledge these barriers and explore the possible measures to mitigate and overcome these barriers to widespread circular practices.

The overarching aim of this thesis is to draw on the direct perception and experience of the actors who engage in the current state-of-the-art circular practices in food by-product management in order to grasp a thorough understanding of these practices and the factors that foster and hinder them. To achieve this aim, three specific objectives have been formulated as indicated below:

First, to examine the current and retrospective experiences of actors on the circular practices adopted in managing food by-products and associated influencing factors – drivers and barriers – with a view of establishing robust qualitative empirical evidence of the feasibility of these practices, setting a solid foundation of their acceptance and diffusion, and grasping insights into what facilitates and slows down the circular diffusion.

Second, to construct a unified taxonomy framework that captures the dynamic interactions of driving and hindering factors and their impacts on the adoption and diffusions of circular practices in food by-product management. The framework establishes multiple institutional logics in the transition from a linear to a circular economy and enables a theory-based classification of factors that influence the shift in dominant logics into two clusters – legitimacy and efficiency. Further, the element of uncertainty is introduced to determine the relative weight of each cluster. When uncertainty is perceived as high in the early transition, the legitimacy cluster that consists of regulatory and normative factors plays a pivotal part. When perceived uncertainty subsides, the efficiency cluster that includes market, supply chain and technological factors becomes determinants.

Third, to delineate useful lessons learnt and suggestions for practitioners and policymakers in the transition towards the circular economy with an informative approach to food by-products management.

1.4 Delimitations

The delimitations of this thesis, boundaries within the researcher's control, are introduced in this part. This study only focused on the homogeneous flow of unavoidable food waste that occurs in large volumes at upstream stages including farming processing and catering services. This waste stream is hereinafter called food by-products. This study will not investigate other types of food waste such as household food waste for two reasons.

First, food waste is often divided into avoidable and unavoidable. While avoidable food waste like a slice of bread, apples, and meat should be preferably minimised or prevented before using any management options, prevention is not an option for unavoidable food waste (Morone *et al.*, 2019). Instead, unavoidable food wastes like eggshells, pineapple skin, and tea bags should be managed to retain their value.

Second, food waste can occur at any stage of the FSC from production, processing, distribution, transportation and storage, as well as the consumption stage. In each stage, the root causes and the extent of food waste issues may vary. For instance, Raak *et al.* (2017) identified three main areas for food waste generations, including food deterioration and spoilage during logistics, by-products discharged from processing plants, and consumer perception of food quality and safety in the consumption stage. Compared to the retail and consumption stages, by-products from upper stream stages such as farming and processing are mostly homogeneous and large in volume in a few geographical proximity areas, which represents a significant opportunity for high-value creation in alignment with the circular economy concept.

It is important to clarify that this scoping in this thesis does not imply that the researcher disregards the significance of managing avoidable food waste. Instead, the researcher believes that both waste streams are equally important to a sustainable food system. The only rationale for a focus on unavoidable food waste emanates from different management approaches applicable to unavoidable and unavoidable wastes as specified above.

1.5 Thesis outline

This presentation of this thesis follows a linear-analytic structure – a standard research approach and the most accepted structure for the case study report as suggested by Yin (2014). The linear-analytic structure initiates with the research problem, then a thorough review of relevant literature, the method employed that includes data collection and analysis, followed by findings and discussions before ending with conclusions and implications. Adopting this sequence, the thesis is organised into seven chapters followed by a list of references and appendices (Figure 1).

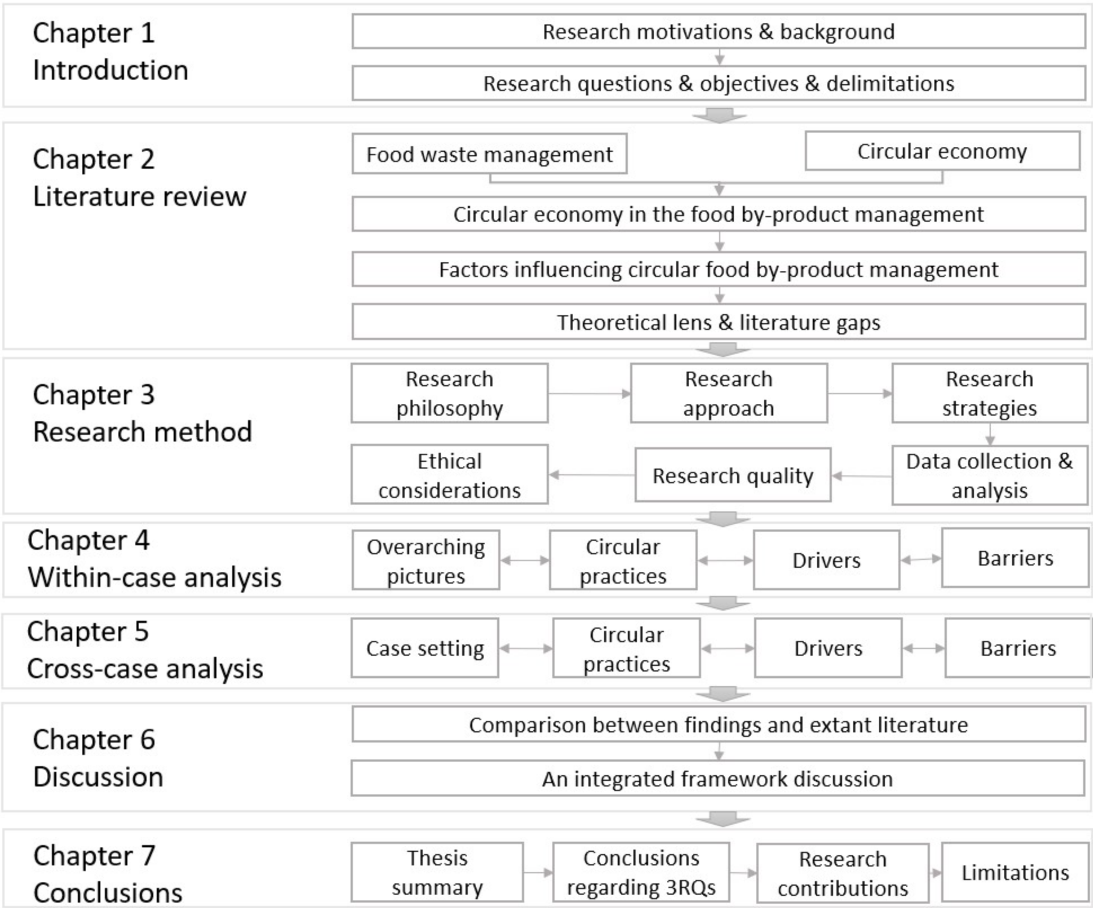


Figure 1: Thesis outline
Source: Created by author

Chapter 1 (this chapter), as highlighted in the previous section, outlines the focus of this research that details its research motivations, research context and problems, research questions and objectives, as well as research delimitations. The rest of this thesis is presented below:

Chapter 2 provides a critical review of prior relevant literature on three topic areas: food waste management, circular economy and institutional theory. Specifically, the chapter gives a snapshot of the circular economy concept with its origins and its peculiar applications in the food waste management areas. Then, the chapter sheds light on the aspects of the institutional theory and justifies this theoretical choice. The most important purpose of this Chapter is the identification of pressing research gaps that offer the opportunity for this thesis to fill in.

Chapter 3 presents the research paradigm, research approach and research method that has shaped the research design. The chapter justifies the choices of underlying paradigm, research approach, research strategies as well as data triangulation sources to be collected and analysed in the circular food by-product management arena. The novel valorisation practices adopted by the food by-product processing cases are the embedded units of analysis that form the circular economy transition. In this chapter, measures taken to assure research quality and ethical considerations are given.

Chapter 4, a within-case analysis, encapsulates the detailed analysis of data in the individual case in terms of circular economy practices and associated determinants. Interview transcripts, field notes, and secondary documents are examined and reported separately in each case.

Chapter 5 presents a cross-case analysis that builds on the ground of the within-case analysis. In cross-case analysis, the pattern matching technique is employed to compare six cases and reveal their similarities and differences. Common strategies for food waste management are explored and identified.

Chapter 6 discusses the major findings and juxtaposes these findings firstly with the extant literature to divulge novel insights regarding three RQs and secondly with the theoretical lens that contributes to refining the integrated institutional theory and enabling analytical generations as well as propositions. A typology for factors that influence each case is developed and discussed.

Chapter 7 summarise the key conclusions with respect to three research questions of the thesis, its theoretical, methodological and practical implications as well as the limitations that suggest suitable opportunities for future studies. In addition, my personal reflections on this long but intellectually fulfilling research journey are presented.

Chapter 2 Literature review

This chapter offers an exploration of both the academic and grey literature relevant to the research phenomenon. This is to establish a connection between what has already been discovered and what is being investigated in this study and reveal what gaps in the interplay of two nascent areas: circular economy and food waste management can be addressed in this research. Specifically, Section 2.1 sheds light on generic areas of food waste management and elucidates the problems with food waste hierarchy. Next, Section 2.2 presents a brief background to the circular economy concept that has increasingly attracted the attention of academic researchers thanks to its capability to decouple economic growth from environmental harm. The discussions of the conceptual framework, conceptual evolutions and fundamental principles in the circular economy are detailed here for the reader to grasp critical insights into this emerging concept. Further, Section 2.3 interpreted how the circular economy principles can be implemented in the management of food by-products. This is followed by Section 2.4 which systematically reviews the influencing factors identified in the circular economy adoption literature. Section 2.5 focuses on the theoretical anchor of this research, the integrated institutional theory. This section explains why institutional theory is a suitable theory for this study and what are the theoretical gaps that circular economy literature has not been addressed. Finally, a critical discussion of existing literature and a summary of emerging gaps that this study aims to fill is encapsulated in Section 2.6.

Of note, this section aims to identify the emergent research streams in the extant literature and highlight literature gaps that offer the opportunity for conducting this research. Hence, the literature review was conducted using the relevant keywords in each section, formulating multiple search strings to maximise the likelihood of getting pertinent articles, then applying these search strings to two well-established scientific databases, Web of Science and Scopus to retrieve abstract and full-text papers. Next, the retrieved full-text papers were thoroughly read and classified into appropriate themes to structure the following analysis.

2.1 An overview of food waste management

This section sketches a holistic picture of food waste management, including how food waste is defined and classified in the literature (Section 2.1.1), how these types of food waste are currently managed by the food waste hierarchy (Section 2.1.2), and what are the problems with waste hierarchy approach which needs to be tackled by the circular economy principles (Section 2.1.3).

2.1.1 Food waste definitions and classifications

2.1.1.1 Food waste definitions

A well-defined definition of food waste is crucial to set a system boundary that supports effective food waste prevention and reduction strategies. Unfortunately, multiple definitions of food waste exist in the literature, which challenges the food waste interventions and monitoring progress (Corrado *et al.*, 2019). A thorough review of these definitions can be found in the review papers such as Corrado and Sala (2018) or Teigiserova *et al.* (2020). This study focuses on discussing three well-known definitions of food waste in the literature, proposed by The Food and Agriculture Organization of the United Nations (FAO), The Food Loss & Waste Protocol (FLW Protocol), and Waste & Resources Action Programme (WRAP).

a) FAO definitions

FAO, a specialised agency of the United Nations, directs international endeavours to achieve zero hunger and food security for everybody, and one of its major concerns is associated with food waste. In its report, FAO has proposed two separate definitions for food loss and food waste following the occurrence stages in the FSC. Accordingly, food waste refers to "*the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food services and consumers*" (FAO, 2019, p. 5). Food loss refers to "*the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retail, food service providers and consumers*" (FAO, 2019, p. 5). In addition, the FAO's definition of FLW excludes: (i) food and/or inedible parts are diverted to an economically productive non-food use (such as feed and biomaterials production), (ii) inedible parts are taken to waste management. Hence, FLW under the definition of FAO only includes edible parts of foods that do not go into feed and biomaterial productions.

b) The FLW Protocol

FLW Protocol is a multi-stakeholder effort that tackles the issues associated with consistently measuring and credibly reporting on FLW. It developed a global FLW accounting and reporting standard, the so-called FLW Standard, that provides guidance to enable a range of organisations and countries to measure and report the quantity of FLW credibly, practically and consistently.

FLW Protocol defines FLW as "*food and/or associated inedible parts removed from the food supply chain*" (FLW Protocol, 2016, p. 3). The definition encapsulates two important components: material types and destinations. First, *the material types* of FLW that include food and/or associated inedible parts. Food refers to any substance—whether processed, semi-processed, or raw—that is intended for human consumption. Inedible parts refer to the components associated with a food that, in a particular FSC, are not intended to be consumed by humans. Inedibility varies among users, and time, and is influenced by culture, socio-economic factors, availability, price, technological advances, international trade, and geography. Second, *destinations* for FLW that removes from the FSC cover 10 possible routes: animal feeds, biomaterial/processing, co-digestion/AD, composting/AD, controlled combustion, land application, landfill, not harvested, ploughed-in, refuse/discards/litter, sewer/wastewater treatment.

Although the definitions of FLW Standard and FAO regarding food, inedible parts, and FSC are consistent, the FLW definition of FLW Standard is different from the one in FAO in two aspects. First, food loss and food waste are not used independently; rather, the single term *food loss and waste or FLW* is used to account for and report food waste issues. Second, FLW in this definition includes inedible parts, whereas FAO excludes them from FLW's scope. Third, though two organisations acknowledge 10 possible destinations for FLW management, FAO excludes animal feed and biomaterial/processing from the FLW scope.

c) WRAP definitions

Waste & Resources Action Programme (WRAP) is a British non-profit organisation that was established in 2000 to ensure sustainable use of resources and production environment and to build a more resilient economy. Waste management for the food and drink sector is one of the key points on WRAP's agenda. In 2020, WRAP issues a guideline for the UK companies in measuring and reporting food waste (WRAP, 2020). In that guideline, definitions for food waste, food surplus and by-products are proposed.

Food waste "describes any food and inedible parts sent to any of the Food Waste Destinations listed below" (WRAP, 2020, p. 15). Eight destinations include anaerobic digestion/co-digestion, composting, incineration, landfill, land application, sewer/wastewater treatment, not harvested/ploughed-in, and unmanaged disposal. *Food surplus* "describes any food and edible parts of foods that are sent to redistribution to people, animal feed or, conversion into industrial products" (WRAP, 2020, p. 15). Notably, due to the difficulty in determining consistently the difference between loss and waste, WRAP uses the term 'food waste' to cover both loss and waste in all stages of FSC. *Food by-product* is "an output from a production process that is not the main intended product, but which has a value as an input to other food, feed or non-food markets" (WRAP, 2020, p. 15). Examples of food by-products are brewers' grain sent for animal feed, and dairy whey sold for protein production. Under WRAP's definition, food waste does not cover food surplus and food by-products.

Compared to FAO and FLW standards, WRAP's definitions are different in two aspects and specified in Table 1. First, the terminology 'food waste' encompasses both loss and waste of edible and inedible parts at all stages of FSC that go into eight destinations only. Hence, the scope of WRAP's food waste is wider than the one in FAO excludes inedible parts but narrower than the one in FLW standard that includes animal feed and biomaterial production. Second, food surplus is introduced and covers the redistribution option, which is excluded in the first two definitions. Among all definitions, food waste and surplus under WRAP have the widest scope.

Table 1: Comparisons of different terminologies regarding food wastes in literature

		Materials		Destinations			Stages of FSC		
Organisation	Terminologies	Edible	Inedible	Redistribution/ food production	Animal feed/ biomaterial productions	Other routes [1]	Harvesting	Process	Retailing, consumptions
FAO	Food waste	x				x			x
	Food loss	x				x	x	x	
FLW protocol	Food loss and waste	x	x		x	x	x	x	x
WRAP	Food waste [2]	x	x			x	x	x	x
	Food surplus	x	x	x	x		x	x	x
	Food by-product	x	x	x	x	x		x	

Source: Created by author

[1] Other routes include anaerobic digestion/co-digestion, composting, incineration, landfill, land application, sewer/wastewater treatment, not harvested/ploughed-in, and unmanaged disposal.

[2] Food waste under WRAP encapsulates loss in its scope and occurs at all stages of the FSC

2.1.1.2 Classification of food wastes

The classification of food waste is crucial for the selection of optimal food waste management alternatives. As such, a number of different taxonomy methods have been proposed in the literature.

The most common method is to dichotomise food waste into edible (avoidable) and inedible (unavoidable) parts (see FAO (2019) and United Nations Environment Programme (2021)). Edible foods, also known as avoidable, refer to "the parts of foods that were intended for human consumption" (United Nations Environment Programme, 2021, p. 9). Inedible parts, also called unavoidable, are "associated with a food that is not intended to be consumed by humans", such as bones, shells, rinds and pits/stones (United Nations Environment Programme, 2021, p. 9). Notably, inedible parts do not consist of packaging or edible parts that have passed the expiry date or been spoiled. Further, some organisations including WRAP add "possible avoidable food" into this classification. Possible avoidable food refers to "*food and drink that some people eat and others do not (e.g. bread crusts), or that can be eaten when a food is prepared in one way but not in another (e.g. potato skins)*" (see WRAP, 2020). This classification is beneficial to guide the actions of practitioners as prevention, also known as reuse, is not pertinent to inedible parts; hence, it is more meaningful to separate inedible parts from food to have a more meaningful food waste reduction target. Despite its merit, the main problem with this classification is that it is subject to physical and cultural elements and context. This has been well-framed in the report of the United Nations Environment Programme (2021, p. 13): "what is considered inedible varies among users (e.g., chicken feet are consumed in some food supply chains but not others), changes over time, and is influenced by a range of variables including culture, socio-economic factors, availability, price, technological advances, international trade and geography".

Another common classification of food waste is based on the possibly recyclable where food waste is divided into suitable for home composting, biowaste collection and non-recyclable food waste. However, this classification is circumstantial as meat and bone can be collected for biowaste recycling in some regions, but not in others; hence, this does not provide comparable results (Lebersorger and Salhofer, 2003).

The most holistic effort in classifying food wastes to assist a more effective management method is captured in Garcia-Garcia *et al.* (2015). The authors proposed a nine-stage classification of food wastes from the top to the bottom as follows (Table 2). First, food waste is divided into two types, edible and inedible parts. Second, edible parts are divided into eatable, spoiled and damaged. Then, edible and eatable parts can be redistributed to people, while inedible parts and spoiled/damaged edible parts are redirected to other methods. Third, food waste is divided into animal- and plant-based origins. Fourth, based on complexity to classify if the waste contains mixed products or a single product. Fifth, if food is or is mixed with meat or animal by-products, it will not be considered for feed production. Only food without the presence of animal products is diverted for feed production. Sixth, food waste is divided based on the occurrence in the FSC, catering and non-catering stages. catering food waste is banned for animal feed. Seventh, animal-based food if properly processed can be used as feed; otherwise, unprocessed animal-based waste goes to AD, composting or land-spreading. Eighth, food is divided into packaged and unpackaged. Next, packaged food that contains non-biodegradable packages must not go to AD, composting, or land-spreading.

Table 2: Nine classifications for food wastes adopted from Garcia-Garcia et al. (2015)

Nine-step classifications	Types of food wastes
(1) Edibility	Edible: foods that are or have been expected to fit for human consumption cereals, fruits, meat, fish, drinks, etc. Inedible: the otherwise, such as fruit skins, stalks, skins, bones, stones, offal, twigs, and peels.
(2) State	Uneatable waste: food that passes expiration date, that is spoiled, or that has been poorly processed. Eatable food: the otherwise, that can be redistributed to human
(3) Origins	Animal-based: contains parts of an animal (like meat, bones, offal) or produced by an animal (like eggs, dairy, honey). Plant-based: otherwise.
(4) Complexity	Mix product: contain different types of foods, such as ready meals Single product: only one type of food.
(5) Animal product presence	Animal products: egg, dairy, honey. Meat: fish, pork, beef, etc. Animal by-products: hides, skins, horns, offal, etc. No contact with animal-based products
(6) Stage of the supply chain	Household and catering stage: hotels, restaurants, households… Other stages: agriculture, processing, retail…
(7) Treatment	Processed: heat-treatment… Unprocessed: raw, uncooked…
(8) Packaging	Unpackaged food: does not contain packages or packages can be easily separated. Packaged food: contain packaging materials.
(9) Packaging biodegradability	Biodegradable packaging: can be digested by microorganisms, suitable for AD or compost. Non-biodegradable packaging: is made of plastic, glass, metal…

While acknowledging various types of food waste classification that have been put forward in the extant literature, this thesis proposes a useful classification of food waste into homogeneous and heterogeneous flows. Heterogeneous flows tend to arise from downstream stages of the FSC including retailers and households and contain a mixture of different types of foods at geographical dispersed locations. This waste flow encounters logistical challenges associated with collection and transportation (Kokossis and Koutinas, 2012), and also difficulty in quantifying the potential scale and composition of this waste stream (Rathore *et al.*, 2016). By contrast, homogeneous flow often stems from the upstream of the FSC including agriculture and processing stages (Banerjee *et al.*, 2018), but in some instances, it can occur at the catering service such as spent coffee grounds (Kourmentza *et al.*, 2018) or used cooking oils at restaurants (Carmona-Cabello *et al.*, 2019). Unlike heterogeneous flows, it is logistically feasible to separate and collect a large quantity of food wastes that are consistent in quality and physiochemical traits at a few locations. This classification offers two noticeable advantages. First, it contributes to the selection of the optimal management options where valorisation to extract high-valuable compounds is commonly suitable for homogenous flows (Girotto *et al.*, 2015) whereas energy and fertiliser conversions, such as AD and composting, are best apt to heterogeneous flow. Second, it overcomes the criticisms associated with the edible and inedible dichotomy as mentioned above.

This thesis focuses on a particular type of food waste, food by-products, which is inedible and belongs to the homogenous flow that is discharged from the upper parts of the FSC because of its suitability in offering a homogenous flow of resources that can be utilised for higher added value generation. The next section will discuss the waste hierarchy for the prevention and management of food waste.

2.1.2 Food waste hierarchy

The principles of the waste hierarchy were introduced in European policy in the 1970s under the 1975 Waste Framework Directive and the EU's Second Environment Action Program in 1977. It was not until 1989 that the waste hierarchy – reduce, reuse, recycle, recovery, and disposal – was clearly defined in the EU’s Community Strategy for Waste Management. Since then, the waste hierarchy framework has been promoted and adopted worldwide. In some Asian countries including Japan, the hierarchy is referred to as the ‘3Rs’ framework where 3Rs stand for reducing, reusing and recycling (Shekdar, 2009; Sakai *et al.*, 2011). In general, waste hierarchy is an inverted pyramid that acts as a reference to guide practitioners to select the most environmentally sound End-of-life (EoL) treatments. In the descending order of environmental outcomes, the food waste hierarchy includes five options: prevention, reuse, recycle, recovery, and disposal. As these options are highly generic for prioritisation of EoL treatments, waste hierarchy is open to different interpretations by the actors and institutions in the application. In the food waste context, multiple waste hierarchy has been proposed and discussed in the literature in the endeavours to achieve a more sustainable resolution of the food waste issue. This study compares and discusses the four popular hierarchies found in extant literature and practice (Figure 2).

First, the earliest effort in translating waste hierarchy to sustainable food waste management was conducted by Papargyropoulou *et al.* (2014). The authors conducted a number of interviews with key stakeholders in the FSC to develop a food waste hierarchy that identifies and prioritises the most appropriate options for dealing with food surplus, avoidable and unavoidable food wastes. At the top of the pyramid, prevention and reuse for human consumption are the most favourable ways to manage food surplus. Once food surplus turns to waste, recycle for feed and composting are the next favourable methods to manage avoidable food waste, while recycling, energy recovery, and disposal are the methods to manage unavoidable food waste in the descending order of preference.

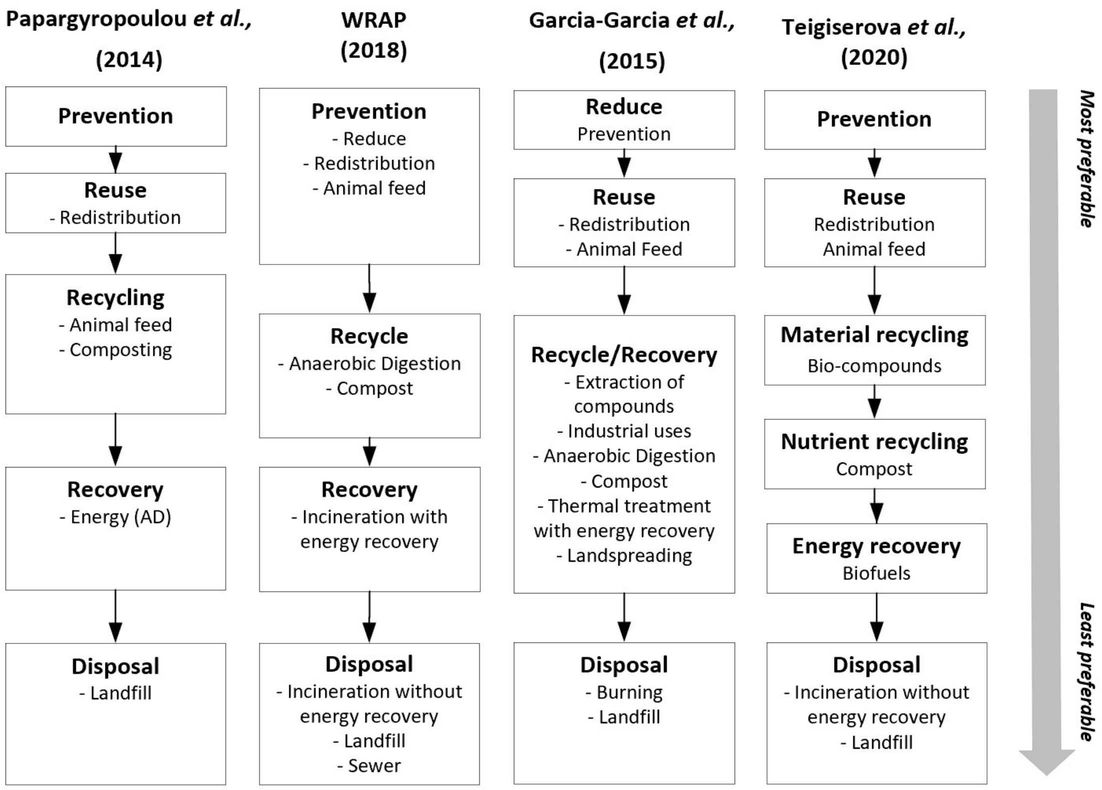


Figure 2: Food waste prevention and management options – A terminology review

Source: Created by author

WRAP (2018) provided a specific material hierarchy that facilitates the business in the UK food and drink sector in the prevention and management of food waste to minimise the environmental impact. WRAP proposed that food surplus should be prevented by three options: prevention at the source, redistribution for human consumption and animal feed, and that food waste, once generated, should be managed by recycling (AD and compost), recovery (incineration with energy recovery), and disposal (incineration without energy recovery, landfill, sewer). Although sharing some similarities in treatment methods with Papargyropoulou *et al.* (2014), the hierarchy in WRAP grouped redistribution for human and feed under prevention strategy, and added incineration and sewer into the disposal group. Of note, the hierarchy of WRAP is consistent with the one proposed by European Parliament that stated "*[…] in food waste prevention and management legislation and policy:(a) source prevention; (b) edible food rescue, prioritising human use over animal feed and the reprocessing into non-food products; (c) organic recycling; (d) energy recovery; (e) disposal*" (Ferrando and Mansuy, 2018, p. 14).

Garcia-Garcia *et al.* (2015) also interpreted the use of the waste hierarchy, which includes *reduce, reuse, recycle and recovery, and disposal*, in the food waste context and offered a more comprehensive pyramid with ten food waste treatments. Reuse refers to the prevention of food waste generation. Reuse consists of redistribution and animal feed production. Recycle and recovery consist of extraction of bio-compound, AD, composting, thermal treatment, and land-spreading. The disposal includes two treatments: burning without energy recovery and landfilling. Similar to other hierarchies, reduce and reuse apply to food surplus while recycling, recovery and disposal are applied to food waste. However, unlike the first two hierarchies, extraction of bio-compounds such as proteins, bioethanol, and essential oils have been supplemented as the most favourable recycle and recovery options.

The most recent efforts in updating the food waste hierarchy under the circular economy context proposed are conducted in the paper of Teigiserova *et al.* (2020). The authors proposed a six-category pyramid that distinguishes food surplus and novel material recycling using biotechnology (Figure 2). Although the pyramids of Garcia-Garcia *et al.* (2015) and Teigiserova *et al.* (2020) appear to be resemblant, Teigiserova *et al.* (2020) made a unique contribution in differentiating recycling for material and nutrient and recovery, which have previously often combined.

In general, these hierarchies all cover five waste management options: prevention, reuse, recycle, recovery, and disposal. However, the scopes of these terminologies are different in these frameworks. Figure 2 encapsulates key ideas of four pyramid frameworks and reflects the fundamental differences in the scope of each term under each framework. It is noted that though Figure 2 does not draw the pyramid shapes of four frameworks, options are ranked in the descending order of preferences from the top to the bottom. In the next section, the shortcomings associated with a pure reliance on food waste hierarchy will be thoroughly discussed to underline the need of having circular management.

2.1.3 Limitations of food waste hierarchy

Despite efforts made to make the food hierarchy more pertinent in the circular economy context, a number of problems associated with this hierarchy can be identified to hinder effective and sustainable food waste management. The thesis discussed four problems in depth:

First, terminological ambiguity challenges the interpretations of the food waste hierarchy. Take animal feed production, for instance. Animal feed is classified as reuse when food waste is heat-treated to produce feed ingredients. However, if food waste is used to extract feed functional ingredients like proteins or to rear insects for larvae, animal feed then becomes recycle strategy. Hence, it is questionable whether heat treatment should be given priority over feed functional ingredients and insect rearing. The same goes for energy recovery located at the very bottom of the waste hierarchy. AD that produces both biogas and digestates can belong to energy recovery (e.g. in Braguglia *et al.* (2017) but can also belong to material recycling (UNEP, 2014). AD and composting are prioritised over gasification. Garcia-Garcia et al., (2016) ranked thermal treatment for biofuel over land spreading but this order is reversed in the hierarchy proposed by Teigiserova *et al.* (2020).

Second, the hierarchy mainly focuses on environmental performance. Economic consideration is limitedly introduced in the place of biomaterial recycling on top of other recovery and recycling options. However, it is advisable that a life cycle analysis should be taken rather than blindly adopting the orders given in the pyramid.

Third, treatment methods are considered in silos. The hierarchy does not reflect the potential for a cascading production of multiple output products. The cascading principle represents a cornerstone in the circular economy approach, which will be discussed in-depth in the next Section.

Fourth, the disposal option is still taken into consideration. Disposals in form of incineration, disposal to sewer, landfill or discarded to sea represent the resource leakage and should be eradicated under the circular economy context. Unfortunately, it is still accepted in the food waste hierarchy.

For these reasons, it is suggested that rather than solely relying on the hierarchical order of the food waste pyramid, only principles of the circular economy should be articulated in the context of food waste management. However, the knowledge of multiple potential options under waste hierarchy gives a solid ground for a flexible application in interpreting the circular economy principle and yielding more sustainable food management outcomes. In addition, given the scope of our study only focuses on food by-product that occurs at the processing stage, not generic food waste at other stages of the FSC, only recycling and recovery fall into our discussion next. In the next section, a conceptual framework for the circular economy will be reviewed and incorporated into the context of food by-product management.

2.2 Circular economy: Concept and historical evolution

This section shows how literature has defined the circular economy concept (2.2.1), how the concept has evolved from multiple schools of thought and introduced in legislation (2.2.2), what are its key principles and how these principles are different between technical and biological cycles (0), and finally how the prior literature has incorporated the circular economy into the food system (0).

2.2.1 Circular economy definitions

The circular economy is of great interest to both academia and practitioners, signified by the rapid growth in the number of peer-reviewed articles and consultancy reports on the topic of the circular economy since 2016 (Geissdoerfer *et al.*, 2017; Kirchherr *et al.*, 2017). The concept was born in response to the enormous pressures caused by the end of the cheap resource era and the mounting environmental impacts associated with the linear model (Lieder and Rashid, 2016). As opposed to the linear make-use-dispose system, a circular system advocates a change in production processes and consumption modes, reduces the need of tapping into virgin materials, minimises or even eliminates wastes, as well as switches to renewable energy (Alonso-Almeida and Rodríguez-Antón, 2020), and thereby gradually decoupling economic activity from the consumption of finite resources and designing waste out of the system. The change endorsed by the circular economy is characterised by a radical and systemic shift that builds a long-term and resilient economy, rather than a little twist of a status quo to the externalities of the linear economy (Kirchherr *et al.*, 2017). For such change to occur, it is imperative to grasp a thorough understanding of what the circular economy entails. Unfortunately, conceptual blurriness is indicated to be a hindrance in the operationalisation of the circular economy. Lieder and Rashid (2016) mentioned multiple possibilities in defining the circular economy while Yuan *et al.* (2006) noted no commonly accepted definitions found in the literature. The abundance of the circular economy conceptualisation, labelled as "the circular economy babble", is accentuated by Kirchherr *et al.* (2017, p. 229) to be a real challenge for the scholars on this topic. Some scholars appeared to have no idea what the circular economy is about. For instance, several equated to 3Rs while neglecting reuse; even worse, some authors constrained the circular economy to recycling. In the following, this study provides the well-recognised definitions of the circular economy in extant literature to increase the transparency of the concept and facilitate its application in the area of food waste management in the latter part of this Section.

In grey literature (such as consultancy reports), a variety of organisations have proposed different definitions of the circular concept (see Dupont-Inglis, 2015; Schut *et al.*, 2016). However, the most prominent one was given by Ellen MacArthur Foundation (2012, p. 7) which states: "*a circular economy is the one that is restorative and regenerative by intention and design*". While "*restoration"* implies the return to an original or previous state in the sense of bringing a degraded ecosystem back to its full function, *regeneration* promotes the self-renewal capacity of natural systems to maintain and improve the current state by revitalising ecological processes that have been damaged or over-exploited by human (Morseletto, 2020). Popular restorative strategies include recycling, cascading, repair, renewal, refurbishment, remanufacture, maintenance, and upgrading with the aim of either maintaining productive use of technical materials and products or reintroducing biological elements back into an ecosystem. On the other hand, *regeneration* is more apt in the agricultural sector where fertility, nutrient recycling and ecological services support the regenerative capacity of nature and thereby enhance natural capital. It is widely agreed that the conceptual distinction between these two concepts is not easy to be drawn (Morseletto, 2020). In the circular economy discourse, restoration and regeneration often go hand in hand to describe a metaphorical aspect of the circular economy. The restorative and regenerative economy is attained by three principles: (i) preserving and enhancing natural capital by better managing materials and balancing renewable resource flows; (ii) optimising resource yields in both technical and biological cycles; (iii) designing out negative externalities and wastes. Three principles enable the achievement of environmental and economic advantage simultaneously. Since this phenomenal work was published in 2012, Ellen MacArthur Foundation continues to publish a series of reports on the nascent circular economy topics (Ellen MacArthur Foundation, 2016; 2017; 2018; 2019; 2020) and acts as a collaborative hub for businesses, policymakers, and academia.

In peer-reviewed articles, hundreds of different definitions have been suggested and captured in several review papers. This study cited two holistic definitions of the circular economy as the result of an extensive review process by Geissdoerfer *et al.* (2017); Kirchherr *et al.* (2017). Geissdoerfer *et al.* (2017, p. 759) proposed the definition that a circular economy is "*a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling"* (Geissdoerfer *et al.*, 2017, p. 759). While this definition is highly aligned with the one in the Ellen MacArthur Foundation (2012), it analogises the circular economy to a cyclical system that is managed by three-loop strategies – closing, slowing and narrowing, which were first introduced by Bocken *et al.* (2016). *Closing loops* aims at completing a resource circle by connecting the post-use of a resource with the production stage via recycling; *slowing loops* focuses on reducing the speed of resource flow by extending the in-use period with long-life design and/or maintenance, repairs, remanufacturing services; and *narrowing loops* emphasises on lowering resources embedded in each product, thereby reducing resource consumption in the system. Narrowing does not influence the speed of the flow of products and does not involve any service loops. Taken together, the closing-slowing-narrowing strategies differentiate the circular economy from merely recycling and recovery.

In a systematic review of 114 definitions, Kirchherr *et al.* (2017, p. 229) employed a coding framework with 17 dimensions and defined the circular economy as "*an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro-level (products, companies, consumers), meso level (eco-industrial parks) and macro-level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers".* The definition specified four core aspects of the circular economy, including (i) the reduce-reuse-recycle-recover (4R) framework, (ii) a systemic shift at macro-meso-micro levels, (iii) enablers of business model and consumers, and (iv) the environmental-economic- social objectives.

This study acknowledges the merits of these definitions in both concise and extensive forms while avoiding reinventing the wheels, the concept of the circular economy used hereinafter follows the definition of Ellen MacArthur Foundation where the circular economy is a restorative and regenerative system by intention and design. Meanwhile, the quintessence of other definitions is reflected in the principles of the circular economy (0).

2.2.2 Origins and historical evolutions of the circular economy concept

While the origin of the term 'circular economy' remains elusive, there is a wide consensus that the idea of a circular economy was introduced as early as 1965 by Kenneth Boulding – an American economist in the paper entitled "*Spaceship Earth*" (Hu *et al.*, 2011), but it is not until 1990 that this term was coined by Pearce and Turner, two British environmental economists, in the work entitled "*Economics of Natural Resources and the Environment*" (Su *et al.*, 2013). Kenneth (1965) analogised the earth to a spaceship that can be eventually destroyed if exploitation and damage continue beyond its recovery/repair capacity. To avoid this fate, the old consumption mode needs to be substituted by a circular one to be capable of continuous reproduction in an ecological cyclical manner. Pearce and Turner (1990) describe the environment as a waste reservoir in an open-ended economy without a build-in tendency for recycling. To surmount the environmental issues and resource scarcity, there is a pressing need to advocate sustainable environment-economic development and see the earth as a closed economic system where a circular relationship exists between the economy and the environment (natural system).

2.2.2.1 Schools of thoughts

As the circular economy cannot be traced back to any particular authors or dates, the concept is considered as the synthesis of various schools of thought (Figure 3), prominently, cradle-to-cradle philosophy, performance economy, blue economy, biomimicry, and industrial ecology (Ghisellini *et al.*, 2016; Geissdoerfer *et al.*, 2017; Merli *et al.*, 2018). These five schools of thought will be discussed in depth in the following.

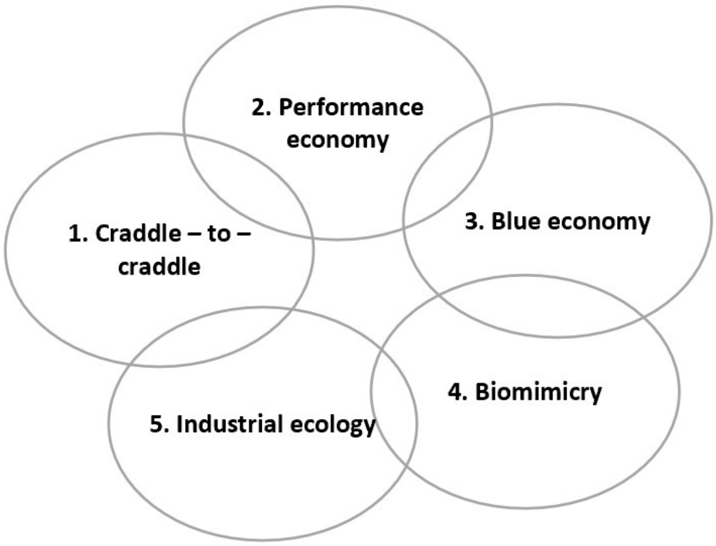


Figure 3: The dominant schools of thought that closely link the circular economy concept

Source: Created by author

First, the cradle-to-cradle philosophy was developed by the chemist Braungart and architect McDonough (2002) to foster the superior design of products for longer use, continuous recovery and re-utilisation (McDonough and Braungart, 2010). This philosophy regards all materials made of two distinct types of nutrients, technical and biological. Food is classified as the consumable products made of non-toxic and beneficial *biological nutrients* that can be safely re-introduced to the biosphere, either directly or via a cascade of consecutive use, to build natural capital. This biological metabolism is in contrast with durable products made of *technical nutrients* (e.g. polymers, alloys) that are not suitable for returning safely to the biosphere and should be designed with minimal energy and the highest quality retention. Building upon cradle-to-cradle philosophy, the circular economy also drives a shift in the material composition of consumable items from technical to biological nutrients to make products serving a restorative purpose, e.g. via the use of bio-degradable instead of single-use food packages. Building on the performance economy, the circular economy focuses on the products' performance, such as having an extended life cycle and consuming less energy and resources (Stahel, 2010).

Second, the performance economy is rooted in the works of Stahel (2010) on the functional service economy. In such an economy, utilisation of resources and extension of the product life cycle are underscored and can be achieved by selling services rather than products.

The blue economy principle is a young concept developed by Pauli (2010) but it is a significant source of inspiration for the construction of a circular economy. Blue represents the oceans or sky that make up the largest components of the planet. Blue economy encourages the use of resources in a cascading manner and promotes the use of wastes of one person to be resources of others, as well as minimises resource leakage (Pauli, 2010). The cascade principle urges the sequential and consecutive utilisation of resources to maximise economic returns. For instance, food waste is used to extract bioactive compounds first before the residues of this process are used for lower value energy and composting production. The promotion of waste exchange in the blue economy supports local production as a basis for sustainable development. The blue economy follows six principles: (i) local consumption (ii) efficiency (iii) imitation of nature (iv) optimisation and generation of multiple cash flows (v) satisfaction of all basic needs (vi) innovative culture.

Third, biomimicry was firstly introduced by Janine Benyus (1997) that recommend the imitations of nature's design in developing environmentally sustainable innovations. Biomimicry came from two Greek words: bios means 'life' and mimesis means 'to imitate'. The self-containing mechanism in nature allows a continuous circular flow without wastes. Take a tree as an example. The dead leaves that fall out are decomposed into minerals to be absorbed by the tree to generate new leaves circularly. Ideally, our food system can be designed following this natural regenerative mechanism. Essential nutrients, such as nitrogen and phosphorous, that have been taken by plants and animals can be fed back to the environment. Hence, biomimicry suggests that the best way to solve our problems and protect nature is to copy its mechanism. Biomimicry aims to create products and processes that function as natural parts of the ecosystem, thereby causing no externalities to the environment. The imitation of the natural ecosystem is the cornerstone of the circular economy concept, which reflects in the regenerative design (Lieder and Rashid, 2016).

Finally, the industrial ecology **theory,** which was developed in the 1980s by Frosch and Gallopoulos (1989), studies industrial processes and their material and energy flow in closed loops (Saavedra *et al.*, 2018). The industrial economy promotes the flow of activities and resources that resemble a natural ecosystem (Graedel, 1996). The most well-known example of the industrial economy theory is an industrial symbiosis that fosters the co-location of traditionally separate companies and industries in a place such as an eco-industrial park to enable the exchange of energy, wastes and by-products and thereby enhancing collective energy and resource efficiency. The real-world examples include an industrial district at Kalundborg in Denmark or the Suzhou New District in China. In the Kalundborg district, a power plant, an oil refinery, a biotechnology facility, a plaster-board manufacturing plant and the local municipality are collocated to facilitate the exchange of energy, materials and waste (Ehrenfeld and Gertler, 1997). Compared to the Kalundborg district, Suzhou New District is much larger and grows fast thanks to the top-down approach from the central government via industrial eco-park initiatives. By 2014, Suzhou New District accommodated above 16,000 enterprises and nearly 4,000 manufacturers (Mathews and Tan, 2011).

2.2.2.2 Circular economy in legislation

The circular economy is believed to be introduced in legislation as early as 1996 in the enactment of the "Closed Substance Cycle and Waste Management Act" in Germany (Su *et al.*, 2013). The law aims to reduce waste by adding product responsibility to product decision-making. Then, it was integrated into the Japanese legal framework when *the Basic Law for Establishing a Recycling-Based Society* came into force in 2002 and provided specific targets for recycling and dematerialisation of Japanese society (Morioka *et al.*, 2005; Van Berkel *et al.*, 2009). The law is praised for its completeness on three levels: basic laws, comprehensive laws, and special regeneration laws that clearly define the responsibilities and obligations of the government and businesses.

In January 2009, China enacted the first Circular Economy Promotion Law that was built on the Cleaner Production Promotion Law in 2003 and the revised Law on Pollution Prevention and Control of Solid Waste in 2005. Unlike laws in Germany and Japan that centre on a narrow scope of waste recycling and less environmental harm, China's circular economy law was endorsed to be a sustainable development strategy that controls resource efficiency at all stages of production, distribution and consumption (Su *et al.*, 2013). China legislation leverages a number of policy instruments such as pollution levies, environment taxes and eco-labelling, cleaner production, energy and water cascading, and the 3R waste management to address resource depletion and severe pollution (Geng and Doberstein, 2008).

In Europe, it was not until December 2015 that a *Circular Economy Package* was released that enables its Member States to go beyond waste management (European Commission, 2015). In 2020, a new ambitious Circular Economy Package with a new action plan was published for attaining a cleaner and more competitive Europe. Not only specifying long-term waste reduction targets and monitoring, but the package also offers initiatives along the entire product life cycle, pursuing better design, fostering circular economy processes, incentivising sustainable consumption, and ideally aims at ensuring the infinite reuse of resources. The EU's transition towards the circular economy is hence seen as systemic, deep and transformative (European Commission, 2020). It is estimated that the adoption of the Circular Economy Package can increase the EU's GDP by 0.5 % and generate 700,000 new jobs by 2030 while halving total greenhouse gas emissions and 90% of biodiversity loss and water use by 2050 (European Parliament, 2020).

Table 3: Legislation promoting circular economy

Country/ year of enactment	Title of legislation and policy	Objective
Germany (1996)	The closed substance cycle and waste management act The Circular Economy Roadmap for Germany	Incorporate product responsibility into economic decision-making to increase the recycling rate
Japan (2000)	The Basic Law to Promote the Establishment of A Recycling-Oriented Society The Basic Plan to Promote a Recycling-Oriented Society of Japan	Legally require manufacturers to run disassembly plants for better material recovery
China (2008)	China Circular Economy Promotion Law	Legalise the circular economy as a law, increase resources utilisation rate, and preserve the environment and sustainable development.
EU (2014)	Circular Economy Package	Close the resource loops via greater reuse and recycling to offer both environmental and economic benefits.
Netherlands (2016)	A circular Dutch economy by 2050	Reduce 50% of virgin materials by 2030.
Denmark (2013)	Denmark without waste strategy	Recycle more, incinerate less

Source: Created by author

2.2.3 Circular economy principles and strategies

From the above discourse of circular economy definitions and historical evolutions with multiple schools of thought, three fundamental principles can be withdrawn from the circular economy transition: (1) preserve and enhance natural capital (2) optimise resource yields at the highest utility and value (3) design out wastes and externalities. The first principle aims toward a more sustainable and infinite circulation of natural resources by encouraging the use of recycled materials instead of virgin and fossil-based materials, as well as the safe return of biomaterials to the ecosystem. The second principle incentivises the utilisation of materials and products in their highest utility and value via technological advances or innovative models. The third principle fosters the use of environmentally friendly production and consumption patterns with little externalities (resource pollution). To facilitate the operationalisation of these principles, four strategies for better resource utilisation and a six-action framework have been proposed by Ellen MacArthur Foundation and will be presented next.

2.2.3.1 Four strategies for material circularity

Efficient and productive use of resources is the core of the circular economy to achieve higher value creation. Resource circularity of an economic system can be achieved with four simple strategies: the inner circle, circling longer, cascaded use and pure inputs as specified in Table 4 (Ellen MacArthur Foundation, 2012). These strategies highlight the unique perspective of the circular economy that considers resource management as the management of loops or circles.

Table 4: Four strategies of circular value creation

Strategies	Description
Inner circle	The larger savings in terms of materials, labour, energy, capital, and externalities yield from the tighter circle. From inner outwards, the circles are ranked: maintain/prolong, reused, refurbish/remanufactured, recycle.
Circling longer	Keeping materials, components, and products in use longer by multiple cycling or by lengthening cycling duration.
Cascaded use	transforms materials across product categories to reduce the virgin resource needs, diversifying reuse across the value chain.
Pure circle	Maintain purity of material and quality of products and components.

Source: Created by author

The power of the inner circle ranks and prioritises the circle based on value creation where a tighter circle generates the most value. Considering each resource management strategy as a circle, some strategies preserve more savings in terms of materials, labour, energy or capital, and thereby these strategies generate higher economic and environmental value than others. These are viewed as inner circles and should be used first before the one in the outer circle. In the butterfly diagram (Appendix 1), which will be discussed in Section 2.2.4, the order of circles from the inner outwards well illustrates this strategy.

The power of circling longer aims to maximise the time in each circle and/or the number of consecutive cycles for products such as by prolonging product life cycle and/or reusing a product multiple times. Circling longer reduces the need of tapping into resources to create new products or parts while optimising the serviceable life of the product.

The power of cascaded use refers to diversifying reuse across the value chain

Cotton clothes cotton clothing is reused first as second-hand apparel then crosses to the furniture industry as fibre-fill in upholstery, and the fiberfill is later reused in stone wool insulation for construction—substituting for an inflow of virgin materials into the economy in each case—before the cotton fibres are safely returned to the biosphere.

The power of pure inputs lies in the fact that uncontaminated material streams increase collection and redistribution efficiency while maintaining quality, particularly of technical materials, which in turn extends product longevity and thus increases material productivity.

2.2.3.2 A six-action framework to promote a circular economy: ReSOLVE framework

The Ellen McArthur Foundation proposed a ReSOLVE framework which represents a set of six actions: Regenerate, Share, Optimise, Loop, Virtualise and Exchange (ReSOLVE) with the objective of defining actions for businesses and policymakers to operationalise the circular economy principles (Ellen MacArthur Foundation, 2012). Each action in the ReSOLVE framework is described in Table 5. These actions complement and reinforce each other to engender a circular economic system and new business opportunities that initiate economic growth.

Table 5: The ReSOLVE framework (modified from Ellen MacArthur Foundation et al., 2015).

Practices	Description
Regenerate	Shift to renewable energy and material; reclaim, retain, and regenerate the health of ecosystems; return recovered biological resources to the biosphere
Share	Share products among users to maximise product utilisation; keep loop speed slow; reuse; prolong product life through maintenance, repair, and design for durability.
Optimise	Increase product performance/efficiency; remove waste from production and supply chain; leverage big data, automation, remote sensing and steering
Loops	Keep components and materials in closed loops and prioritise inner loops
Virtualise	Dematerialise by delivering utility virtually such as books, music, online shopping, autonomous cars or virtual office.
Exchange	Replace old materials with advanced non-renewable materials; apply new technologies; choose new products and services

Source: Created by author

Although the ReSOLVE framework is proposed by the non-academic organisation, it has been widely utilised in the academic discourse. For instance, in a systematic literature review paper by Merli *et al.* (2018), authors coded extant literature based on six strategies specified in the ReSOLVE framework and revealed that the loop strategy attracts nearly 50% of academic discourse, followed by optimising and generating strategies. Similarly, Jabbour *et al.* (2019) and Chiappetta Jabbour *et al.* (2019) elaborated on how the ReSOLVE framework plays an essential role in the circular economy transition in the integration with the large-scale data environment and with the human resource management, respectively.

2.2.4 Technical versus biological cycles

The application of the above-mentioned strategies and actions are different for technical and biological cycles, and these differences are captured in the circular economy butterfly diagram proposed by the Ellen MacArthur Foundation (Appendix 1), which separates biological flow (left-wing) and technical flow (right-wing). The diagram indicates the belief that technical materials which are finite can be used in a closed-loop society through sharing, maintaining, reusing, remanufacturing and recycling of products. On the contrary, biological materials can flow in an open-loop environment of resources cascading through sequential steps of bio-based material extraction, energy conversion, and nutrient recycling to the biosphere to feed the next cycle of primary produce. To facilitate the understanding of the differences between the two cycles, Table 6 provides brief descriptions of key terminologies in the butterfly diagram.

Technical cycles refer to the management of finite non-renewable resources, also known as abiotic resources, that cannot safely cycle in and out of the biosphere, and therefore, these resources are designed to be reintroduced to the techno-sphere for as long as possible via a series of reuse, refurbish, remanufacturing and recycling. Once mined (for inorganic materials) or produced (for synthetic materials), their value is retained as much as possible via prioritising inner cycles (maintenance, reuse, repair), amplifying the number of consecutive cycles and prolonging the time spent in each cycle (Ellen MacArthur Foundation, 2015). For example, a computer, a durable product, is mostly made of plastics and metals that are unsuitable for the biosphere; hence, it should be designed from the start for reuse, and an array of circles for repair and refurbishment of products and remanufacturing of technical components.

Biological cycles, on the other hand, involve the open-loop flows of renewable resources, also known as biotic resources, that can safely loop back to the biosphere. Biological cycles are designed so that products can be consumed or to be cascaded and subsequently decompose in the biosphere (Bocken *et al.*, 2016). Food is a typical example of the biological cycles that can be safely returned to the biosphere.

In theory, the differences between biological and technical cycles appear to be discernible, but they are not easy to be distinguished in practice because often resources contain a mixture of biotic and abiotic materials either owing to their natural composition or owing to their technical design. Recent trend advocates the shift from technical nutrient to biological nutrient where biotic resources are used to produce alternatives for non-biodegradable consumables such as bio-based polymers.

Having said that, the circularities in biological and technical cycles are different and require separate approaches. In the ReSOLVE framework, regenerate is less apt to the technical cycle whereas loop and virtualise are less applicable to the technical cycle. In addition, while the progress towards the circular economy needs a balance in achieving technological and biological cycles, existing circular economy literature mainly focuses on the former – the extent to which resources are looped back in the techno-sphere. The circularity of biological cycles receives far less attention (Genovese *et al.*, 2017). In this thesis, the focus on foods, a typical product made up of biological nutrients, contributes to advancing the knowledge in this underexplored area.

Table 6: A review of terminologies used in the butterfly diagram (Ellen MacArthur Foundation, 2015)

Biological cycles-related terms		Technical cycle-related terms	
Terms	**Definitions**	**Terms**	**Definitions**
Biological cycle	Placed on the left-hand side of Ellen MacArthur Foundation butterfly diagram that involves the flow of *biotic materials* that can be appropriately returned to the *biosphere*; hence, it is designed to harvest resources from ecosystems, and then cascade them through multiple materials applications, before decomposing at the end of their life cycle to safely re-enter biosphere and restore the natural capital.	Technical cycle	Placed on the right-hand side of Ellen MacArthur Foundation butterfly diagram that involves flows of *abiotic materials* that cannot be appropriately returned to the biosphere; hence, it is designed to circulate resources in a perpetual cycle of production, recovery and remanufacture in the *techno*-sphere without entering the biosphere
Biotic resources	Refer to living organic matter formed by the biological system using atmospheric carbon and solar energy (such as silk or wood). They are intrinsically renewable.	Abiotic resources	Refer to inorganic (e.g. minerals, metals) and non-living matter (e.g. fossil fuels) or synthetic material from non-living matter (e.g. fossil-based plastic). By nature, they are non-renewable or finite by nature.
Biosphere	Refers to the part of the Earth and its atmosphere occupied by living organisms.	Techno-sphere	Refers to parts of the human system, which is a physical environment built or modified by humans. It is considered a sub-system to the biosphere.
Biological nutrients	Refer to non-toxic and can be composted. It is encouraged to make many short-live products and consumables.	Technical nutrients	polymers, alloys, and other man-made materials. Many long-live assets such as buildings and roads are made of technical nutrients.
Bio-degradable	Refers to the capability of being degraded under the action of micro-organisms.	Non-biodegradable	often refers to synthetic products like plastic, glass and batteries. those who cannot be decomposed or dissolved by natural agents. not capable of being broken down by the action of living organisms
Pertinent strategies	Reuse, recycle, recovery in cascading loops.	Pertinent strategies	Maintenance, reuse/redistribute, refurbish/ remanufacture, recycle

2.2.5 Circular economy in the food system

This section elaborates how literature explores the adoption of the circular economy in the FSC – a typical example of biological cycles. In general, the literature discussed different strategies to build a circular food system associated with three segments: production, consumption, and food waste management.

Regarding food production, production practices advocate food grown regeneratively and locally where appropriate. Regenerative practices in agriculture aim to build long-term health for the agricultural sector by shifting from synthetic fertilisers to organic fertilisers made of recycled nutrients (particularly phosphorus), employing intensive agricultural practices, and using greater crop variation to promote biodiversity. These practices improve soil heath, thereby increasing crop yields, reducing pest number, restoring natural capital, and enhancing food tastes and nutrient content. Local production fosters peri-urban production selecting varieties best fitting local conditions, thereby adding more resilience to the food system that relies on a diverse set of local, regional, and global sources.

Regarding food consumption, as consumers play a vital role in the circular transition, their food consumption decisions and patterns are crucial to building a circular food system. Sustainable consumptions include a more environmentally friendly eating pattern such as a less meat-cantered diet and a preference for local products such as a Nordic diet that emphasised native seafood consumption rather than industrially produced meats.

Regarding food waste prevention and management, food should be designed to cycle so the by-product of one firm provides input for the next. While surplus eatable foods are redistributed, the remaining inedible foods are converted into new products ranging from organic fertilisers for regenerative farming to energy and biomaterials through emerging technologies and innovations (Morone *et al.*, 2019).

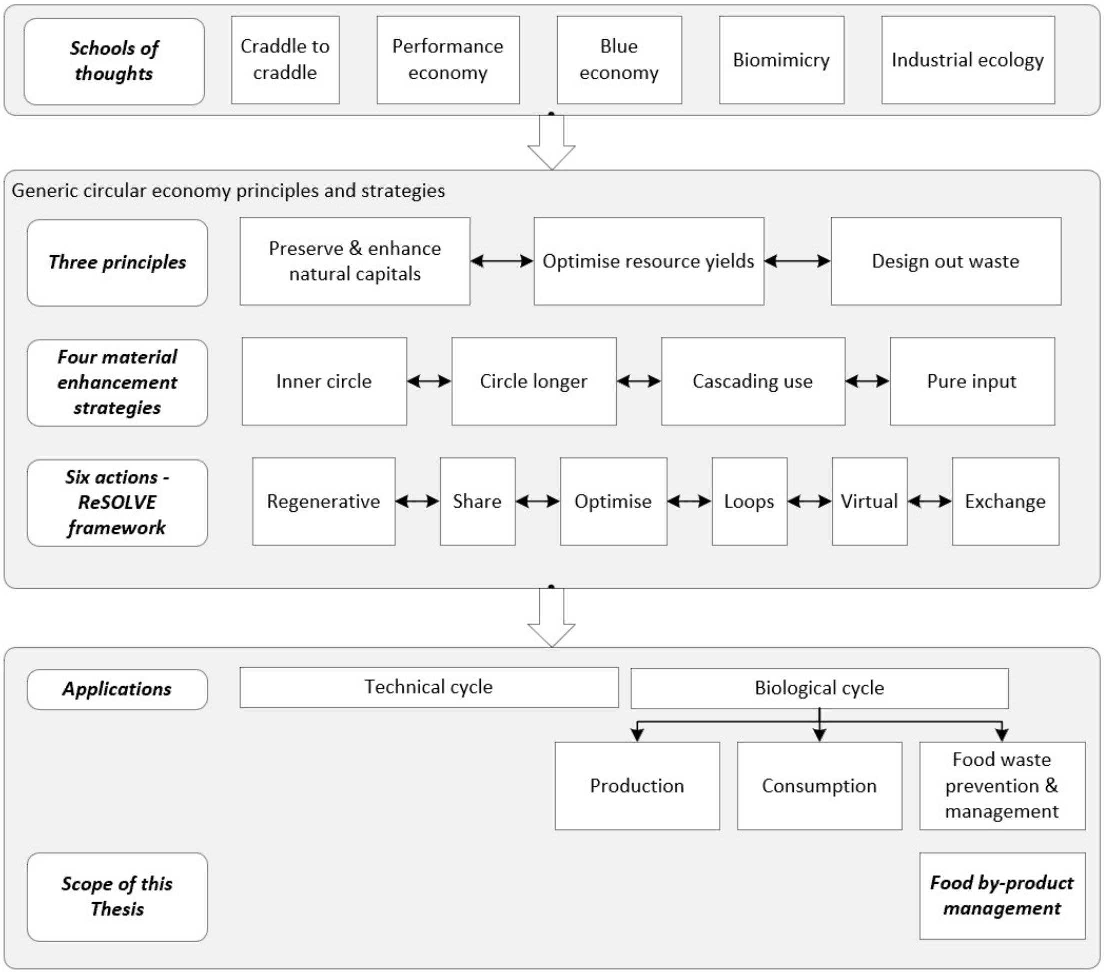


Figure 4 Scoping the research interests in the circular economy literature

Source: Created by author

A true circular food system can only be achieved in a balance of sustainable production, consumption, and waste prevention and management. Of note, these stages are not separated but intrinsically linked, such as local and sustainable consumption facilitates local production and contributes to waste reduction at the source. However, due to its scale and severity, food waste prevention and management is placed in the spotlight in the extant literature and is considered to be an integral part of a circular economy transition (Vilariño *et al.*, 2017). As discussed earlier in chapter 2.1, food waste prevention and management are not the same for edible (avoidable) and inedible (unavoidable) parts of foods. The scope of the study is only limited to the food by-product management, not involving surplus and food wastes arising at other stages of the FSC. Figure 4 demarcates and positions this study's focus in the broad circular economy literature. In the following, only relevant principles in the circular economy literature for unavoidable food management are extracted and applied.

2.3 Circular economy in food by-product management

2.3.1 Principle of the circular economy in food by-product management

This section has provided a substantial review of the circular economy and delineated the scope of the paper in the wide context of the circular economy. This study only focused on the food waste management segment which is a part of the biological cycle. Hence, only the following aspect of the circular economy can be applied to food waste management. *Principle 1* encourages the production of bio-based materials and energy to replace fossil-fuel counterparts. effective returns of nutrients back to the biological cycle, eliminate resource leakage. This is linked to the regenerative practice in the ReSOLVE framework. Principle 2 fosters the cascade use to produce multiple resources and inner circle. This is associated with cascade use, inner circle and circler longer undervalue utilisation. Principle 3 aims to the reduction and ideally eliminate the toxic chemicals to ensure a pure circle.

To facilitate its application, this thesis rephrases three principles to foster the later analysis of practices: (1) Higher value retention that aims at the generation of higher added value products (HVAP) (2) Cascade use via biorefinery to produce multiple outputs (3) Green technology that fosters the use of greener technologies, less toxic chemicals. These principles have been mentioned in silos in the circular food waste literature. Hence, this study contributes to systematically bringing together these three principles and explicitly articulating how they can be translated into the food by-product management areas.

2.3.1.1 High-value biobased material production

As the circular economy aims to retain products, components and materials at their highest utility and value, it is crucial for practitioners to consider the economic value of output products in the valorisation decisions. Both grey and academic literature have discussed categorisation methods in facilitating such a decision-making process.

Valorisation refers to the conversion of FLW into high-value bio-compound and animal feed (FUSIONS, 2014) while full valorisation means a cascading biorefinery before energy and soil restoration options (Ellen MacArthur Foundation, 2012). Valorisation receives considerable attention in the review sample (i.e. Mirabella *et al.*, 2014; Zabaniotou and Kamaterou, 2019) and is normally applicable to manage the "homogeneity of the waste flows" (Corrado and Sala, 2018, p. 129) e.g. by-products at the processing plants. Insect-rearing on plant-based FLW, such as fruits and vegetables, for feed production, is also a type of valorisation (Barbi *et al.*, 2020); and this trend marks a shift away from simple thermal food-to-feed conversion (Cappellozza *et al.*, 2019; Conti *et al.*, 2019).

A useful reference for practitioners to select valorisation options based on economic value is the *biomass value pyramid*. The pyramid (Figure 5) developed by BioBased Economy Netherlands (Davis *et al.*, 2017) states that in the descending order of value, the desirable output products are ranked as (i) nutraceutical and fine chemicals (ii) food, (iii) feed, (iv) bulk chemicals (like solvents, bioplastics, bio-fertilisers), and (iv) energy. As the higher environmental performance does not always coincide with higher economic value, the biomass value hierarchy is somewhat contradictory to the food waste counterpart discussed earlier where priority is given to food and animal feed over fine chemicals. However, as long as environmental benefits can be justified, the biomass value pyramid is beneficial to support practitioners' decision-making in the circular economy transition.

In academic literature, some efforts are made to classify the end products derived from food waste. For instance, Xiong *et al.* (2019) divided output products into consumer chemicals, speciality chemicals, commodity chemicals, and niche chemicals. First, consumer chemicals (using bio or thermal conversion) refer to daily life products that are directly interacted with end-users such as cosmetics, vitamins, health supplements, soaps, detergents, household chemicals, perfume and flavour. Food waste is normally valorised to extract volatile fatty acids (VFAs), lactic acid, citric acid, succinic acid, and ellagic acid to produce these products. Second, refined speciality chemicals (using extraction) indicate performance chemicals, which enhance the properties and functions of other products such as antioxidant biomaterials, essential oils, protein, and fibres. Third, commodity chemicals refer to the bulk chemical in high global demand such as biofuel, biogas, and biochar. Finally, niche chemicals (such as chitosan, glucose, and free amino nitrogen) refer to the chemicals that target a specific profitable industry. This classification is not only valuable for economic value ranking because speciality and niche chemicals often offer higher marketable value than consumer and commodity chemicals, but this also facilitates technological choices.

Notably, the types of materials and products to be recovered depending on the types of food by-product feedstocks. For instance, in a review paper on the prominent end-products extracted from three types of food waste, Mirabella *et al.* (2014) found out that fruits and vegetable by-products are often examined for antioxidants, fibre, phenols, polyphenols and carotenoids extraction, while meat and its derivatives are primarily for protein extraction, and dairy is commonly studied for lactic acid, proteins and peptides.

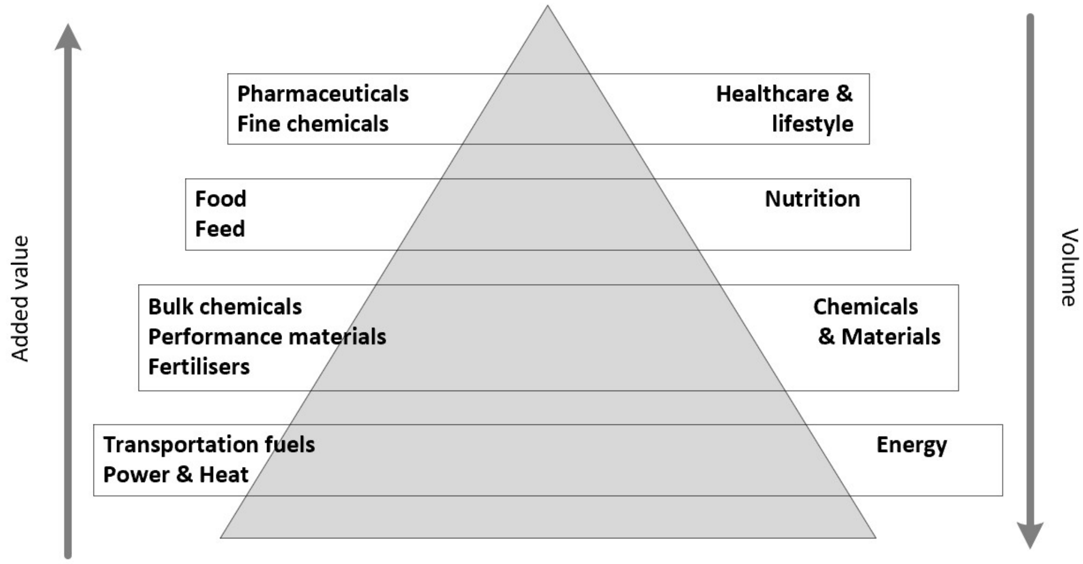


Figure 5: Biomass value pyramid (modified from BioBased Economy Netherlands in Davis *et al.,* (2017))

2.3.1.2 Cascading biorefinery

Cascading use was firstly proposed by Sirkin and ten Houten (1994) and originated in the forestry sector where wood is allocated in a cascade of three sectors: wood processing, paper production and energy sector (Keegan *et al.*, 2013). The wood industry discharges sawmill residues that are fed into the paper sector, and then papers are recycled in the energy sector. Cascade is defined as "*optimising resource utilisation through a sequential re-use of the remaining resource's quality from previously used commodities and substances*" (Sirkin and Houten, 1994, p. 217). In simple terms, cascading use advocates the diversified use of materials prior to their conversion into energy at the bottom of the food waste hierarchy. Biomass, including food by-products, should be utilised to produce HVAP such as fine chemicals and nutraceuticals first before the residues are used to generate those with presumably lower values including food, followed by feed, bulk chemicals and finally energy (Berbel and Posadillo, 2018). Not all the valorisation pathways have the same value and options increasing the cascading use of resources is preferable (Corrado and Sala, 2018).

Compared to the mono-process that relies on complete disintegration of by-products, cascading use that leads to optimal utilisation of resources offers significant resource efficiency gains. Higher resource efficiency not only reduces the need of tapping into virgin resources but also shifts away from the use of toxic materials that impair material reuse, thereby alleviating the environmental burden. In principle, the chain of cascading uses starts with an effective separation and extraction of multiple materials and compounds. However, the political landscape in some countries such as in Europe is skewed toward energy conversion rather than biomaterial extraction.

In food waste literature, cascading and biorefinery are often used interchangeably despite inherent differences. Biorefinery, analogous to a petroleum refinery, is defined as the "*sustainable processing of biomass into a spectrum of marketable products and energy*" (Cherubini *et al.*, 2010, p. 4) where "products" here refer to both intermediates and final products, such as food, feed, materials and chemicals. On the other hand, cascading implies a linear process in which food by-products go through a series of material cycles by reuse and recycling before finally being used for energy extraction. However, they are not mutually exclusive but complementary, so the term *cascading biorefinery* is commonly detected in food waste valorisation literature and emphasised as cornerstones of the circular bioeconomy (Venkata Mohan *et al.*, 2016; Ingrao *et al.*, 2018; Zabaniotou, 2018; Caldeira *et al.*, 2020). In cascading biorefinery, multiple processes are integrated into an optimised sequence to covert by-products into multiple marketable intermediates, products and energy.

Numerous examples of cascade biorefinery using food by-products as feedstocks are found in the literature. For instance, Dahiya *et al.* (2018) proposed a food waste-based biorefinery approach that integrates various bioprocesses (including acidogenesis, fermentation, methanogenesis, solventogenesis, photosynthesis, oleaginous process, bio-electrogenesis) to simultaneously produce multiple HVCP including biofuels (H2, CH4, biohythane, biodiesel), platform chemicals (sugars, carboxylic acids, bioethanol, biobutanol), bioelectricity, biomass, biomaterials (biopolymers), biofertilizers, animal feed. Cristóbal *et al.* (2018) estimated the techno-economic feasibility of biorefineries that use four types of food processing wastes: tomato, potato, orange and olive in Europe. Other biorefinery models focus on a single type of by-products, such as olive oil by-products (Berbel and Posadillo, 2018; Gullón *et al.*, 2020); potato and orange peels (Matharu *et al.*, 2016); spent ground coffee (Kourmentza *et al.*, 2018; Zabaniotou and Kamaterou, 2019); mushroom (Banasik *et al.*, 2017); avocado seeds and peels (Del Castillo-Llamosas *et al.*, 2021). In a laboratory experiment, Alexandri *et al.* (2019) looked into a three-stage process to convert sugar beet pulp into phenolic compounds and pectin, sugar, and then succinic acid. Similarly, Mussatto *et al.* (2013) experimented with the co-production of xylitol, lactic acid, activated carbon and phenolic acids from brewer's spent grains (BSG) in Brazil. Despite demonstrating the feasibility of the biorefinery approach, most of the papers are in the form of review studies and laboratory experiments. There is a need to supplement the empirical evidence by using real-world cases to elaborate on how the cascading biorefinery can be implemented, and this thesis aims to fill in this gap.

2.3.1.3 Green technology

There are a plethora of technological options that enable the extraction of bio-based materials from food by-products and can be grouped into three pathways: thermochemical, physicochemical and biochemical processes. Thermochemical technologies such as pyrolysis, gasification, incineration, plasma arc gasification, liquefaction, and carbonization use high temperatures to convert feedstocks into fuels, electricity and heat and HAVP. Physicochemical technologies such as transesterification use chemical agents to convert feedstocks into liquid fuels and biomaterials. Biochemical technologies such as AD and fermentation use biological agents to convert different types of feedstocks into liquid and gaseous fuels and bioproducts. However, not all these technologies are environmentally friendly, and therefore, might not fall into the green spectrum of the 'design-out waste' principle and pure circular strategy. Hence, a circular economy guides the practitioners toward the choice of greener technology to reduce the externalities associated with material circulation. In addition, greener technology is the foundation for the first two principles as the presence of toxic chemicals can damage the property of materials in the biomass, which hinders the cascading biorefinery and production of bio-materials suitable for food and supplement markets.

The focus on green technology in food by-product valorisation has been well captured in recent academic literature, exemplified by a series of review papers, such as Mirabella *et al.* (2014); Dahiya *et al.* (2018); Xiong *et al.* (2019). This thesis encapsulates the prominent technologies used in food by-product valorisations from three mainstream processing sectors: meat, fruits and vegetables, and dairy (Table 7).

Table 7: Typical technological options for the valorisations of food by-products in different sectors

Sectors	Typical technologies	Targeted end-products	Applications
Meats including fish	Enzyme hydrolysis Fermentation Green extraction ($SCF-CO_2$, SWE, HHPE, EAE, HPTE)	Protein Bioactive peptides Collagen Enzyme Oil (rich in PUFA)	Nutraceuticals Medical Food Feed Biomaterials
Fruits and vegetables	Extraction (UAE, MAE, PLE, $SCF-CO_2$, HHPE) Fermentation	Phenolic compounds Pectin Dietary fibres Seed oils Lactic acids and sugar	Nutraceutical Food
Dairy including eggs	Membrane filtration technology (whey)	Protein Lactic and fatty acids	Food Pharmaceutical
	Centrifugation (eggshells)	Calcium carbonate	Range of industrial, cosmetic, and medical applications

Source: Created by author

(1) For meat by-products including fish and crustaceans, growing interest is paid to the extraction of protein, collagen, bioactive peptides, enzyme, oils, as well as chitin and its derivatives. Protein, collagen and bioactive peptides are hydrolysed using enzyme hydrolysis (Ahn *et al.*, 2012;

Lapeña *et al.*, 2018; Bechaux *et al.*, 2019; Borrajo *et al.*, 2019). While protein can be used to replace the ingredients in animal feeds and human foods, the bioactive peptide has a high antioxidant activity for industrial and medical applications. Collagen and gelatine (C&G) are extracted from skins or hides, bones, tendons and cartilages. Its extraction from pig skins was initiated in the 1930s and achieved large-scale industrial production while growing attention is now paid to C&G from fish by-products (Gómez-Guillén *et al.*, 2009; Jongjareonrak *et al.*, 2010) but its production scale makes it uncompetitive compared to pig skins (Mirabella *et al.*, 2014). In addition to these outputs, interesting avenues for fish by-product valorisations are the production of enzymes and fish oil. The enzymes, including protease and esterase, can replace synthesised chemicals in the food, medical, cosmetic and textile sectors. Microbial enzyme production uses fermentation to process fish heads and viscera (Ben Rebah and Miled, 2013; Caldeira *et al.*, 2020). Fish oil that contains polyunsaturated fatty acids (PUFAs) rich in Omega-3, -6, -9, is commonly valorised for nutraceutical applications. Fish oil is extracted from fish by-products using green extraction technologies including Supercritical Fluid Extraction with CO2 (SFECO2), Subcritical-Water Extraction (SWE), High Hydrostatic Pressure Extraction (HHPE), and Enzyme Assisted Extraction (EAE) (Ferdosh *et al.*, 2015; Monteiro *et al.*, 2018)

(2) For fruits and vegetable products, popular high-value end-products that attract academic attention include seed oil, phenolic, and pectin. *Seed oil* is extracted using SFE-CO_2 such as on peach seeds in Ekinci and Gürü (2014) or on passion fruit seeds in Barrales *et al.*, (2015); EAE on pomegranate seeds in Talekar *et al.*, (2018); Ultrasound-Assisted Extraction (UAE) and Microwave-Assisted Extraction (MAE) on kiwi seeds in Cravotto *et al.* (2011). *Pectin*, a polysaccharide present in the cell wall and middle lamella of plant tissue, is extracted using SWE from apple pomace and citrus peels (Wang *et al.*, 2014), MAE on watermelon rinds (Maran *et al.*, 2014), UAE on pomegranate peels (Moorthy *et al.*, 2015), EAE and HPPE on lime peels (Naghshineh *et al.*, 2013) or chicory roots, cauliflower florets and leaves (Zykwinska *et al.*, 2008). *Phenolic compounds* are recovered by using UAE on grape pomace (Nayak et al., 2018), SFE-CO_2 on apple pomace (Adil *et al.*, 2007) or grape (Da Porto *et al.*, 2015). Other bioactive compounds like carotenoids (such as lycopene, lupeol and mangiferin) are extracted using MAE, SWE, HPPE, UAE, and SFE-CO_2 (Ruiz-Montañez *et al.*, 2014). These studies validate the benefits of novel green extraction which is less time and energy consuming and has higher yields compared to conventional solid-liquid extractions using toxic organic solvents (Cravotto *et al.*, 2011; Pingret *et al.*, 2012; Naghshineh *et al.*, 2013).

(3) For the dairy sector, whey is the main liquid by-product with high protein and fat content derived from cheese production factories. It is estimated that each year EU releases 50 million cubic meters of whey from nine million tons of cheese production (Kosseva, 2011). Whey has

been studied for protein and lactic acid fermentation in literature. Protein is recovered by various membrane filtration technologies (diafiltration, ultrafiltration, nanofiltration) to reduce fouling and purify why protein (see Wen-qiong *et al.*, 2019). Lactic acid is another product recovered from whey due to the presence of lactose and minerals via fermentation (Soriano-Perez *et al.*, 2012; Rama *et al.*, 2019). Eggshell In this segment, eggshell is another by-product that attracts attention. Eggshells are produced for calcium carbonate using grinding, and centrifugation.

2.3.2 Summary of food by-product management under the circular economy

In summary, the circular economy distinguishes biological from technical cycles as they entail different management approaches. Food is a typical product representing the biological cycle but attracts much less attention compared to technical counterparts in circular economy academic discourse. In the food system, food waste prevention and management emerge as an integral part of the circular economy transition and have been receiving growing interest. Food waste prevention and management are further dichotomised into the management of edible and inedible parts of foods due to different strategies involved. This study limits the attention to only homogeneous edible foods that are discharged from the food process stages, also referred to as food by-products. A clear boundary allows the researchers to identify three underlying principles in broader circular economy literature that are relevant to the management of food by-products.

- High-value material production: prioritise the production of end-products with higher marketable value, particularly in those in pharmaceutical and nutraceutical markets.
- Cascading biorefinery: aims towards the production of multiple high-value end-products.
- Green technology: encourages the use of eco-friendly technology that consumes less time and energy without the presence of toxic chemicals.

This is the first time that all three principles are explicitly articulated in the food by-product management under the circular economy context. This contributes to advancing literature on the topic and differentiating circular food by-product management from food waste hierarchy. Since literature review signifies a relative paucity of empirical evidence on how these principles can be implemented, the practical case studies investigated in this thesis are expected to fill in this void. In addition, the identification of these principles enables the researcher to identify three dimensions associated with the first research question: "*how can the circular economy be implemented in the food by-product management*", which includes technology, output products and markets for these products. Specifically, the researcher investigates what types of technologies these cases employ, what types and how many end materials or products are generated, and which market these products and materials are sold into.

Next, the researcher explores how literature addresses the drivers and barriers in the circular economy implementation in the management of food waste including by-products.

2.4 The factors influencing food waste management in the circular economy transition

The exploration of drivers of and barriers to the generic circular economy implementation is one of the emergent topics (Leder *et al.*, 2020). A number of systematic literature reviews have been carried out (see de Jesus and Mendonça (2018); Govindan and Hasanagic (2018)), and several classification ways have been proposed. For instance, Kirchherr *et al.* (2018) identified and categorised 15 barriers to the circular economy transition into four groups: *cultural, regulatory, market and technological*. Authors blamed these barriers for the limited circular economy implementation in practice and noticed the chain reaction mechanisms among these barriers. By contrast, Tura *et al.* (2019) proposed a seven-group framework for the classification of drivers and barriers, which consists of *environmental, economic, social, political and institutional, technological and informational, supply chain, and organizational* factors. The authors emphasised the highly context-specific nature of drivers and established information technology as a central role in the circular economy transformation. Most recently, Russell *et al.* (2020) interviewed the informants in the Dutch circular economy initiatives and found 18 critical factors to be grouped into five categories: *financial, institutional, policy and regulatory, technology and knowledge, and social*. Because drivers and barriers are highly context-specific (Tura *et al.*, 2019), increasing attention is paid to the different business environments, such as automotive (Agyemang *et al.*, 2019; Urbinati *et al.*, 2021); mining (Upadhyay *et al.*, 2021); construction (Kanters, 2020); and waste management – reduce, reuse, and recycle (3Rs) (Ranta *et al.*, 2018), as well as the food industry (coffee in van Keulen and Kirchherr (2021) and meat and dairy in Gregg *et al.* (2020)). When it comes to the differences in managing materials made of technical nutrients and biological nutrients, some factors such as enablers of repairs or product recall in the former are not applicable in the latter. It is imperative to conduct a dedicated review that addresses how literature investigates the drivers and barriers in the circularity of by-products in the food sector.

The next section will follow a systematic approach in reviewing drivers and barriers in the FSC context under the circular economy to provide a holistic picture of the phenomenon. A systematic literature review is a process of "*a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of completed and recorded work* *produced by researchers, scholars and practitioners*" (Fink, 2019, p. 6). A systematic review enables a rigorous, impartial, and literature-wide assessment of extant studies' outcomes, quality and design. It helps to overcome the major criticisms associated with the narrative method of reviewing articles, which include being devoid of replicability, transparency and thoroughness and thus can be biased by the researchers in making sense of extant literature (Tranfield *et al.*, 2003).

2.4.1 Review process

Following the seminal work for conducting and SLR by Tranfield *et al.* (2003) and the content analysis-based literature review method of Seuring and Gold (2012) that was built on the work of Mayring (2008), we organised our reviews in three phases:

Step 1: Choice of keywords and search strings

The choice of keywords aims to maximise the likelihood of locating scientific contributions that fulfilled the paper's objectives. Keywords are chosen from three topics: *(1) drivers and barriers* (keywords used such as driver, enabler, facilitator, hindrance, barrier, challenges); *(2) food waste management* (keywords used such as food by-products, food wastes, or residuals) *(3) circular economy topic* (keywords used such as circular economy, circularity, or circular bio-economy). Truncated terms (* sign) for keywords were used as recommended in Gimenez and Tachizawa (2012) to expand the range of possible studies found.

The keywords were queried on two databases, Scopus and Web of Science, which have been considered the most comprehensive databases of peer-reviewed journals that store a broad range of scientific papers (Chadegani *et al.*, 2013; Nobre and Tavares, 2017; Mokhtar *et al.*, 2019). Additionally, both databases have been used extensively in producing SLR in the field of circular economy (Homrich *et al.*, 2018; Merli *et al.*, 2018; Türkeli *et al.*, 2018; Sehnem *et al.*, 2019) and food waste management (Chen *et al.*, 2015; Ferrazzi *et al.*, 2019; Gorzen-Mitka *et al.*, 2020). The merge of two databases is beneficial to increase the likelihood of capturing all the relevant contributions and to provide a high level of rigour in searching and selecting the papers to be included in the subsequent analysis (Centobelli *et al.*, 2017). Of note, in Web of Science the research field was "Topic" (Title, Author Keywords, Abstract, Keyword Plus"), while in Scopus, the search field was "Title, Author, Keywords, Abstract". No chronological restriction was employed. The queries were performed on January 2021. The search on Scopus returned 120 papers in Scopus and 98 papers from Web of Science is obtained.

Step 2: Material selection and evaluation

To focus the research on the topic under investigation, these papers are then screened in this step by applying a series of inclusion and exclusion criteria.

(1) Selecting only peer-reviewed articles written in English
(2) Removing duplications between two databases
(3) Removing overlapping between Scopus and Web of Science
(4) Screening the abstract and content for relevance: only papers that can retrieve full-text and explicitly address the identification and classification of drivers and/or barriers in the food waste valorisations under the circular economy. Any papers that focus mainly on avoidable food waste prevention and reduction are excluded from the scope of this thesis.

This also facilitates the comparison between our findings and those found in extant literature in the Discussion.

Step 3: Content analysis

After retrieving a full text of 15 articles, these papers are summarised and synthesised to distil a list of relevant drivers and barriers to the adoption of the circular economy in food waste management. Table 8 summarises the key findings in these articles in a chronicle time. The most exhaustive list of influencers in agri-residue valorisation is provided in Donner *et al.* (2021). They also proposed a classification framework for these factors in five groups: (1) technical and logistic, (2) economic, financial and marketing, (3) organisational and spatial, (4) institutional and legal, and (5) environmental, social and cultural factors. Some other papers only limit the attention to several types of influencing factors or certain geographical locations. For example, only policy and technological barriers were investigated in Joshi and Visvanathan (2019) for four food waste management routes in Asia: animal feeds, anaerobic digestion (AD), AD composting, and incineration. Five Asian countries were explored by Ong *et al.* (2018) to identify drivers and challenges in converting food waste into animal feed, energy and platform chemicals.

Next, the study will present a brief description of the sources of drivers and barriers found in these papers. This enables the comparison with the findings in Section 5 of this thesis.

Table 8: Peer-reviewed articles that investigate drivers of and barriers to food waste management under the circular economy

	Name	Scope	Food waste types
1	Pal and Suresh (2016)	5 scale-up challenges: seasonality, consumer acceptance, food safety, quality, and market value of end-products.	Seafood by-products
2	Borrello *et al.* (2016)	7 challenges: regulation, reverse logistics, geographical dispersion, system boundaries,	Bread by-product

		consumers' acceptance, technology, investment uncertainty	
3	Ong *et al.* (2018)	Drivers: food security, environmental protection, and energy efficiency Barriers: legislation, financial/technical support from private sectors, consumers' compliance	Generic food wastes in developing countries
4	Banerjee *et al.* (2018)	Challenges: product quality (nutritional value), seasonality, product market value, logistics issues for plant scale-up	Pineapple by-products
5	Joshi and Visvanathan (2019)	Technological and policy drivers	Generic food wastes in developing countries
6	Teigiserova *et al.* (2019)	Two challenges: regulation, lack of market research for colourants, and quantification challenge due to food waste definition.	By-products
7	Gregg *et al.* (2020)	*7 drivers:* policy and governance, business strategies, economics, demand, innovation, research and development, and actors and networks. *Barriers:* less market pull, low technical capability	By-products from the dairy, slaughterhouse, beer brewing, forestry
8	Boumali *et al.* (2020)	*3 drivers*: economic gains, collaboration, policy *6 barriers*: technology, organisational capability, market acceptance, network complexity, vertical integration, and institutional lock-in.	Apricot pits
9	Nawaz *et al.* (2020)	5 challenges: regulation; biotechnology; product quality (nutritional, textural, sensorial, bioavailability, interaction with other ingredients);	Seafood by-products
10	Sadhukhan *et al.* (2020)	Barrier: policy, low industrial support	By-products
11	Gedam *et al.* (2021)	18 barriers in 7 groups: economic, IT, SC, Policy, social, organisational, environment	FSC
12	Donner *et al.* (2021)	60 critical success factors and 28 risks in five groups: technical and logistics; economic, financial and marketing; organisational and spatial; institutional and legal; environmental, social, and cultural factors.	Agricultural waste and by-products
13	Santagata *et al.* (2021)	Opportunities and challenges from 3 sources: technology, economic and culture.	By-product
14	Aschemann-Witzel and Stangherlin (2021)	Drivers: environmental concerns Barriers: consumers' acceptance of end-product	By-product
15	Leder *et al.* (2020)	*Drivers:* Collaboration, technology, top management commitment. *Barriers:* technology and cost, traceability, space, policy, stakeholders' perceptions	Generic food wastes

Source: Created by author

2.4.2 Drivers for food waste management in the circular economy transition

Literature has identified a list of drivers from the following groups: regulations, commitment from top managers, economic gains, technology, supply chain, collaboration, and consumer trends.

Regulatory drivers: These come from a mix of laws and regulations, incentives and funding, prizes and awards, and awareness campaigns. Stricter environmental laws such as the whey disposal law (Gregg *et al.*, 2020) and the relaxation of regulations such as enabling the use of slaughterhouse by-products in the AD plants drive valorisation efforts (Donner *et al.*, 2021). Regulative drivers also derive from the availability of fiscal incentives (Donner *et al.*, 2021) and public funding for research and development (R&D) projects in food-waste valorisation (Ong *et al.*, 2018; Boumali *et al.*, 2020). Prizes and awards for circular innovation efforts are an important driving force behind the valorisation projects (Donner *et al.*, 2021). Finally, government initiatives to increase citizens' awareness are another driver in this group (Joshi and Visvanathan, 2019).

The commitment of top managers: this is a driving force to look for technologies that allow the recovery of valuable nutrients and energy from this resource (Joshi and Visvanathan, 2019), and to engage in cleaner production to rectify the environmental issues associated with food wastes (Joshi and Visvanathan, 2019; Leder *et al.*, 2020), as well as to reduce human dependencies on virgin resource depletion (Joshi and Visvanathan, 2019; Santagata *et al.*, 2021).

Economic gains: These stem from the cost benefits of acquiring input materials at a cheap price and insignificant logistics costs – most preferably when by-product producers incur a cost of disposal (Sheppard *et al.*, 2020).

Technological drivers: These derive from a range of technological options for food waste treatment, including biotechnology and non-solvent treatments (Sheppard *et al.*, 2020), especially in the case of AD – a marketable technology (Donner *et al.*, 2021). Biochemistry advancement is the key enabler for the success of the biorefinery model in the dairy industry (Gregg *et al.*, 2020).

The supply chain driver: this is another crucial driver because processing residues are often found in large quantities with consistent quality and traceability assurance (Donner *et al.*, 2021).

Collaboration drivers: these occur among stakeholders that enable information sharing and facilitate the adoption of circular economy in the unconventional non-food production route (Boumali *et al.*, 2020; Leder *et al.*, 2020).

Consumer trends: these spur the interest in buying 'green' products generated by transparent and traceable bio-based production processes, and particularly locally produced from nature-based functionalities (Gregg *et al.*, 2020; Donner *et al.*, 2021). Notably, customers include both consumers and business-to-business (B2B) customers (Leder *et al.*, 2020). An example of consumers' interest in the biowaste-based process is the higher acceptance of the decentralised AD compared to centralised ones, facilitating the former to secure the financial capital (Joshi and Visvanathan, 2019).

2.4.3 Barriers to food waste management in the circular economy transition

The literature under this review identifies a list of barriers that come from five sources: regulatory, technological, economic and market, supply chain, and stakeholders' attitudes.

Regulatory barriers: These arise from insufficient laws and regulations, ineffective enforcement capacity, and a lack of government incentives. First, legal barriers consist of ineffective recycling policies, ambiguity in waste disposal policy (Sadhukhan *et al.*, 2020), changes in agricultural waste management legislation, complex and region-specific legal regulations (Leder *et al.*, 2020; Donner *et al.*, 2021), as well as restrictions on the reuse of by-products due to food safety and quality concerns (Santagata *et al.*, 2021). Regulatory barriers also encompass the absence of a legislative framework to govern trading in the by-product market (Boumali *et al.*, 2020; Leder *et al.*, 2020) and bureaucratic safety approvals of novel end-products (Donner *et al.*, 2021). Second, ineffective law enforcement capability consists of inadequate law monitoring and even insufficient budget allocations (Joshi and Visvanathan, 2019). Third, a lack of incentives may exist in the forms of insufficient public funding in the scale-up phase and an absence of subsidies (Donner *et al.*, 2021), as well as misaligned incentives that prioritise valorisation routes at the bottom of the waste hierarchy, such as energy conversion (Sadhukhan *et al.*, 2020).

Technological barriers: These have been accentuated in the majority of extant literature. First, current technologies for treating food waste, except AD, have a low technology readiness level (TRL) and experience numerous upscaling challenges (Boumali *et al.*, 2020; Nawaz *et al.*, 2020; Donner *et al.*, 2021). Furthermore, technological adoption requires the possessions of high technical competence and skilled labourers (Boumali *et al.*, 2020) to enable the integration of new technology into the existing business model (Leder *et al.*, 2020). Then, the financial hurdle owning to a long payback period associated with novel technological development is the third barrier in this group; for example, it is estimated that an AD plant for meat by-products, despite having a relatively high TRL, has a payback period of 4.3 years (Gregg *et al.*, 2020). Lastly, there are concerns associated with the end products in terms of safety, sensorial and nutritional aspects, and interactions with other ingredients (Pal and Suresh, 2016; de la Caba *et al.*, 2019; Nawaz *et al.*, 2020). There is thus a pressing need to evaluate the safety and bioavailability of nutrients, particularly for nutraceutical products.

Economic and market barriers: These encompass the dearth of stable demand for end products (such as those made of slaughterhouse by-products in Gregg *et al.* (2020) or apricot pits in

Boumali *et al.* (2020)), the uncompetitive prices of new bio-based products compared to the cheap and highly volatile fossil-based products and energy that dominate existing markets (Donner *et al.*, 2021; Santagata *et al.*, 2021), high market entry barriers for new products (Donner *et al.*, 2021). Non-price competitiveness can be attributable to the immature and pilot-scale processes as well as the complex bio-composition of by-products (Donner *et al.*, 2021). There is also concern about the competition between multiple valorisation pathways for the same waste feedstocks (Donner *et al.*, 2021).

The supply chain barriers: These comprise sourcing variations due to seasonal, local and compositional attributes of by-products, which could pose risks for continuous manufacturing (Pal and Suresh, 2016; Joshi and Visvanathan, 2019; Donner *et al.*, 2021); the necessity of efficient, flexible inbound and outbound logistics, as well as large storage capacity for both materials and end products (Leder *et al.*, 2020; Nawaz *et al.*, 2020; Donner *et al.*, 2021). These logistical challenges arise from the special traits of by-products that are often bulky, heterogeneous, and highly perishable.

Stakeholders' attitude: These contain low interest among processors in the bio-based production using agricultural by-products as feedstocks (Boumali *et al.*, 2020; Leder *et al.*, 2020); the choice of valorisation pathways constrained by traditional, cultural and religious factors (such as the use of meat by-product for human consumption (Gregg *et al.*, 2020)); and low consumer trust in novel biowaste-derived products like biofuels (Donner *et al.*, 2021).

2.4.4 Gaps in the drivers and barriers

The section showed how the extant literature explores the drivers and barriers influencing the generic circular economy transition and its implementation in food by-product management. Compared to the generic circular economy transition, the interests in the circular food by-product valorisation are much more limited. Further, a list of 15 peers reviewed articles were retrieved using a systematic review approach and analysed the content in-depth. Following gaps are identified:

First, none of the papers under review explores the drivers and barriers using primary data from real cases. This is caused by the limited number of circular by-product valorisation businesses in the food sector. Hence, the explorations from the stakeholders who actually engage in the practical business offer valuable insights that can enrich the extant knowledge of the determinants in the circular economy transition.

Second, the number of drivers and barriers found are highly context-dependent. Although overlap is seen in the list of factors identified in different articles, the number of drivers and barriers vastly vary from article to article. This is partly explained by a variance in the investigations' scopes. While some focused on generic food waste, including surplus and edible foods, others only paid attention to a single by-product type. Similarly, some papers investigate the Asian context while others review articles without geographical constraints. However, it is widely agreed that an empirical study with a clear boundary of investigation bridges the gap between academic and practical knowledge.

Third, there is no consensus on the classification of drivers of and barriers to the circular economy transition in food waste management. While technology and policy emerge as the central hindrances, social and market factors attract growing attention. Besides, it is unclear how these factors interact in the process of achieving circular transition. Particularly, it is debatable about what the practitioners and policymakers can learn and leverage the knowledge of the drivers to overcome these barriers. To put it simply, the question of what can learn from the list of drivers and barriers to facilitate the circular economy transition should not be ignored.

In light of these issues, this paper aims to augment the drivers and barriers associated with the empirical evidence for food by-product valorisations and borrow the theory-based approach to offer a meaningful classification of the influencing factors on the circular transition.

2.5 Theoretical lens

2.5.1 A review of theories used in the circular economy transition

This section aims to identify and compare potential theoretical underpinnings that have been used in literature to address the research questions identified in this thesis. It is a common perspective that borrowing theories from other areas contribute to deepening and expanding knowledge of a discipline (Kauppi, 2013) as well as bringing rigour and focus to addressing specific questions and aims (Leder *et al.*, 2020). Hence, this thesis will leverage a well-established theory to enrich the knowledge of the circular economy implementations with associated drivers and barriers.

In generic circular economy literature, many theoretical lenses of other disciplines can be borrowed to investigate the circular economy phenomenon. In the systematic review article of Liu *et al.* (2018), a list of theories have been identified to be used or have the potentials to be used in the circular economy studies, which include resource-based views (RBV), resource dependency theory, institutional theory, stakeholder theory, social network theory, diffusion of innovation theory, industrial symbiosis theory, ecological modernisation theory, social capital theory, systems theory, social exchange theory, theory of production frontier, complexity theory, transaction cost economics, agency theory, information theory (also known as signalling theory), cluster theory, theory of socio-technical transactions, social embeddedness theory, knowledge-based view, endogenous growth theory, ecosystem theory, social cognition theory, and evolutionary theory. Interestingly, the circular economy literature uses these theories with hesitations (Liu *et al.*, 2018; Leder *et al.*, 2020).

Among these theories, five theories have been utilised in extant literature to detect the influencing factors of the circular economy implementations. These theories are stakeholder theory, transaction cost economic, and resource-based view, social capital theory, and institutional theory. In the following, each theory will be analysed and summarised with references to the circularity literature before a justification for the theoretical choice in this study is presented.

2.5.1.1 Stakeholder theory

Stakeholder theory was introduced and popularised in the works of Donaldson and Preston (1995); Friedman and Miles (2006) to highlight the capability of organisations in responding to stakeholders' pressures (Mani and Gunasekaran, 2018). A stakeholder is defined as "*any group or individual who can affect or is affected by the achievement of the organisation's objectives*" (Freeman, 2010, p. 46). Hence, stakeholders can be individuals, organisations, or governments that have an interest in the actions of an organisation (Mitchell *et al.*, 1997). In the circular economy domain, literature underscored the significance of stakeholder involvement in the circular economy transition (such as in Ghinoi *et al.*, 2019; Gupta *et al.*, 2019). While some papers focus on internal stakeholders such as employees (Govindan and Hasanagic, 2018), others underline the pressures from external stakeholders, typical governments and industrial partners, or media (Genovese *et al.*, 2017; Russell *et al.*, 2020).

Stakeholder theory has been successfully employed to identify drivers and barriers to the circular economy implementation in several papers. For example, Chiappetta Jabbour *et al.* (2019) discovered the triggers of human resource management in the circular economy. Similarly, Meherishi *et al.* (2019) found the drivers of sustainable packages in the circular economy. Jakhar Suresh *et al.* (2019) investigated drivers and barriers from different stakeholders in the circular economy initiatives. Most recently, Chiappetta Jabbour *et al.* (2020) anchoring on stakeholder theory built and tested a research framework that captures the interactions among stakeholder pressure, obstacles to and drivers of the circular economy, circular business models, and sustainable outcomes of firms.

2.5.1.2 Transaction cost theory

Transaction cost theory is developed by Williamson (1981) and awarded with Nobel Prize. The theory is used to predict whether the different governance types of hierarchies, markets, or hybrids (e.g., alliances) could be employed, or whether any activities of the firms would be internalised depending on their transaction costs. The theory gives insights into how companies should design contracts or choose the set-up to ensure mutual benefits in novel circular business, and to reduce unforeseen contracting costs that derive from, for instance, incompetence contract partners, or high complexity contracts (Lahti *et al.*, 2018; Werning and Spinler, 2020).

Transaction cost theory is beneficial in pinpointing the transaction-related factors influencing circular economy adoption. For instance, Dossa *et al.* (2020) revealed transactions with high asset specificity function as an indirect driver of circular economy adoption via assurance/certification schemes by reducing uncertainty levels. Domenech *et al.* (2019) mentioned a range of transaction costs such as transportation and learning costs as obstacles to industrial symbiosis under the circular economy.

2.5.1.3 The resource-based view (RBV)

The resource-based view (RBV) establishes the link between resources, capabilities, and competitive advantage by arguing that a firm's competitive advantage is built on the capability to reconfigure its resources (Barney, 1991; Hart, 1995). Although a resource can be anything that the firm possesses at its disposals such as capital, tangible assets, employee knowledge, processes, or relationships, in order to be a resource under RBV, this resource needs to qualify for VRIN attributes which stand for Valuable, Rare, Inimitable and Non-substitutable (Barney, 2001). The firm is required to identify and manage this VRIN resource to stand out in the market and build a sustainable advantage (Wernerfelt, 1984).

RBV enables the identification of VRIN resources as drivers for firms to develop circular economy capabilities, such as in Bag *et al.* (2021) who considered two types of resources – tangible resources and employees' skills – as a driver for enhancing technology and adopting sustainable manufacturing practices, thereby developing circular economy capabilities. Likewise, Mishra *et al.* (2019) explored how collaboration can be a facilitator of the circular economy transition through value creation from the circular business model and human sphere.

2.5.1.4 Social capital theory

Social capital theory (SCT) proposes that interpersonal relations generate value for individuals because they offer resources that can be employed to attain desired outcomes. There are two elements in the SCT: a social element (norms and values) and a capital element (money and value) where the former emphasises collaboration in a social relationship/structure/network and the latter focuses on the embedded resources in such collaborative network (Lin, 2002). In other words, collaboration matters more than individual development according to SCT. Hence, SCT incentivises actors to work together more efficiently to pursue shared goals (Putnam, 1995). From the network perspective, three activities are employed to build social capital: bonding, bridging and linking (Claridge, 2018). In a network, bonding promotes horizontal ties while bridging supports vertical ties. Linkage establishes the connections between communities and social, political and economic institutions.

In the circular economy literature, Leder *et al.* (2020) used SCT to explore any influential factors to this circular business model in waste valorisation. The authors propose that enablers for the waste valorisation models are the interplay between three factors: value creation, collaboration and technology.

2.5.1.5 Institutional theory

As institutions are social structures that are formed by humans to offer stability and meaning to life, the institutional theory emerges to address questions of how and why organisations adopt similar institutional arrangements (Meyer and Rowan, 1977). The institutional theory postulates the role of established and resilient social structures that provide societal stability via three pillars: regulative, normative, and cultural-cognitive (Scott, 2014). These pillars are individually distinguishable but interdependently exert the coercive, normative, and mimetic pressures, respectively, to influence the organisational behaviour in a specific sector, community or region (DiMaggio and Powell, 1983). Institutional theory has reached its prominence as a powerful explanation for green or sustainable endeavours at both firm and individual levels to explain the diffusion and adoption of sustainable businesses.

In the transition toward the circular economy, literature has established that the institutional environment can accelerate or slow down the adoption of the circular economy (Ranta *et al.*, 2018; Leder *et al.*, 2020). For example, rules can be a facilitator if they give punishment for the wasteful behaviour, but they can be a barrier when they deny the reuse of specific products. Likewise, the normative pillar, such as the guidance that recycling is more acceptable than landfilling, is a circular economy driver; but if the normative pillar indicates that the reduction of greenhouse gas is more beneficial than landfilling, it becomes a circular economy inhibitor. Various circular practice adoptions have been investigated in the literature, including environmental reporting practices (Dagiliene *et al.*, 2020), lean and green practices (Caldera *et al.*, 2019), outsourcing and internal separation (Stål and Corvellec, 2018), and adoption of sustainable packaging (Meherishi *et al.*, 2019).

2.5.1.6 Theoretical choice

Table 9 provides a comparison of five theories used in extant circular economy literature to examine influencing factors. Given our research questions and aims, the institutional theory appears to be the best theoretical anchor for several reasons.

Table 9: A summary of theories used in extant circular economy literature to examine influencing factors

	Scope of application	**Unit of analysis**	**Example articles**
Stakeholder theory	To examine the influence of stakeholders in the circular economy implementations	Stakeholder level	Chiappetta Jabbour *et al.* (2019); Jakhar Suresh *et al.* (2019); Chiappetta Jabbour *et al.* (2020)
Transaction cost theory	To identify factors escalating or driving down the transaction costs in the circular economy transition	Transaction level	Domenech *et al.* (2019); Dossa *et al.* (2020)
RBV	To underline VRIN resources (e.g. collaboration, employee skills) as facilitators to the circular economy achievement.	Tangible/ intangible resource level	Mishra *et al.* (2019); Bag *et al.* (2021)
SCT	To explore factors influencing the accumulation of social capital in the circular economy transition	Network-related level: bonding, bridging, linking	Leder *et al.* (2020)
Institutional theory	To investigate factors facilitating or hindering circular economy implementations of the organisations in the same field.	Factor level (regulative, normative, and cultural-cognitive)	(Ranta *et al.*, 2018; Leder *et al.*, 2020).

Source: Created by author

First, institutional theory has its explanatory power to examine and classify the factors that lead firms to be *isomorphic*, or similar in their actions/inactions of the firms (DiMaggio and Powell, 1983; Turkulainen *et al.*, 2017). It takes a macro approach considering laws, legislation, social norms and managerial cognition to reveal the factors influencing firms in the same field, unlike RBV, transaction cost or SCT that hold true at the micro-level of individual firms. As the circular economy transition cannot be achieved at the individual firm level, a system or macro analysis is more pertinent.

Second, institutional theory has reaped its popularity in detecting the drivers of and barriers to circular economy implementation. Factors causing mass actions in the circular economy transition are considered to be the drivers while factors leading to inactions are viewed as the barriers. Technically, the institutional theory is more interested in identifying pressuring factors rather than stakeholders, but these pressures arise from various stakeholders, including governments, competitors, society, consumers, etc. Given the research questions and objectives, we believe that institutional theory yields higher explanatory power.

Taken together, the researcher believes that the institutional theory offers a best-fit theoretical anchor to enable the achievement of this thesis's objectives. The researcher chose to borrow the lens of institutional theory and at the same time advance its explanatory power in the circular economy context. In the following section, the institutional theory will be discussed in-depth to underline some theoretical gaps and unique theoretical contributions that this thesis aims to attain.

2.5.2 Institutional theory in the circular economy

The preceding section exposes how the institutional theory is currently used in extant circular economy literature, which gives rise to two significant theoretical gaps that the study aims to fulfil. *First*, extant literature places primary focus on the inherent stability of an institutional system to explain the "*homogeneity*" of phenomena such as the adoption of a particular circular practice. However, *heterogeneity* can also be explained by the institutionalists due to different responses from firms to the institutional pressures (Greenwood and Hinings, 1996; Hoffman, 2001; Bunduchi *et al.*, 2008; Greenwood *et al.*, 2010; Bhakoo and Choi, 2013). In food by-product management, heterogeneity is evident in the context that some of the firms follow traditional low-risk routes such as AD or animal feed production, while others take risks to engage in biotechnological development for higher yield. In this regard, the explanatory power of heterogeneity in the institutional theory should be harnessed. Prior literature often uses the concept of "institutional logics" to account for heterogeneity (Thornton and Ocasio, 2008). To my researcher's knowledge, the use of institutional logic in the circular economy transition has not been investigated. As the thesis is grounded in the context of a circular economy transition that involves subtle systemic changes from a linear production and consumption model, the exploration of changes in the institutional logic is highly pertinent in this transition. Further insight into the institutional logic is presented in section 2.5.2.1.

Second, the extant literature on the circular economy only sheds light on the sociological variant of the institutional theory where firms adopt a particular circular practice for "legitimacy" reasons due to three institutional pressures: coercive, normative, and memetic. Nevertheless, as a circular economy is an economic concept that enables higher efficiency, firms can be motivated to adopt a circular practice for "efficiency" reasons. As such, the circular economy offers a possibility to integrate two variants of the institutional theory into a single analytical framework. Section 2.5.2.2 brings more light to this integrated institutional theory.

2.5.2.1 Institutional logics

This section shed light on the power of institutional logic in the circular economy transition. This thesis subscribes to the definition by Thornton (2004, p. 70) on institutional logics: "*assumptions and values, usually implicit, about how to interpret organizational reality, what constitutes appropriate behaviour, and how to succeed*". In a simple term, it refers to the belief system and related practice that is prevalent in an organisational field (Scott, 2014). Institutional logic offers a shared understanding and bonding among actors in the same field (Zucker, 1987) that contributes to shaping their cognition and behaviours and thereby affecting the extent to which homogeneity or heterogeneity can be seen in the environment (Thornton and Ocasio, 1999). In this regard, Thornton and Ocasio (2008, p. 104) elaborated: "*Rather than positing homogeneity and isomorphism in organizational fields, the institutional logics approach views any context as potentially influenced by contending logics of different societal sectors*". Of note, institutional logic dated back to the dawn of institutional theory in the study of Alford & Friedland (1985) but became popularised with the surge of research on institutional changes.

There is a mutual relationship between the institutional forces and institutional logic (Sayed *et al.*, 2017). The perception of the pressures may be influenced by the prevailing logic. A current overriding logic in the environment makes actors perceive institutional forces differently. Institutional logic, once they become dominant, leads to the action or inaction of firms by drawing the managers' attention to a set of solutions and issues that are consistent with them (Zucker, 1987). A shift in dominant logic, therefore, shifts the attention of firms towards those actions that conform with the paradigm, which ultimately induces change (Thornton and Ocasio, 2008).

A growing number of literature has examined institutional logic in different contexts (Thornton and Ocasio, 1999; Besharov and Smith, 2014) and revealed the dynamics of institutional logic regarding their evolution over time (e.g. in Thornton and Ocasio, 1999) and contradictions and competition between the different logics at one point in time (Greenwood *et al.*, 2010; Besharov and Smith, 2014). For example, Thornton and Ocasio (1999) studied a shift from an editorial logic to a market logic in the Higher Education Publishing Industry. Greenwood *et al.*, (2010) examined the co-existence of multiple logics, such as regional state logic, family logic and market logic that induces multiple responses in a complex institutional context.

Although institutional logic has not been leveraged in extant circular literature, it has been scantly used in generic supply chain management (SCM) studies. In operations and SCM literature, rare attempts have been made to incorporate the institutional logic. Some exceptions can be named. For example, Gawer and Phillips (2013) investigated a shift from traditional supply chain logic to new platform logic in the computer industry. Similarly, Heiskanen (2002) explored the life cycle thinking as a new institutional logic that impacts the environmental management practice of wholesale-retail purchasers. In the food sector, Glover et al. (2014) studied different logic in the dairy supply chain and found that financial logic is predominant in this chain, which causes difficulties for the actors to establish a sustainable logic. Likewise, Sayed *et al.* (2017) examined how prevailing institutional logic aids the successful implementation of sustainable SCM in the food and catering supply chain.

By ascertaining the institutional logic of the circular economy, the study contributes to tackling a lack of a unified understanding by theorising circular economy that involves a change in the dominant logic. This logic can be utilised as a code of conduct governing behaviour and decision-making in the chain of reasoning that facilitates the transition from a linear to a circular economy. The thesis posits that the by-product management is in the circular economy transition; hence, the researcher is interested in exploring the logic of the circular economy that the actors in the by-product management area aim to establish, and whether these logics are dominant in the by-product management in the UK context. The concept of institutional logic fits well with RQ1. Based on how the stakeholders describe the circular practices in terms of expectations and pathways, the logic of the circular economy in current food by-product management can be interpreted. This thesis applies an explorative case study research strategy to explain the institutional logic of the practitioners within the industry.

2.5.2.2 An integrated institutional theory

The institutional theory examines the factors that engender 'isomorphism' or homogeneity in the ways organisations shape their structures, strategies, and processes (Kauppi, 2013); hence, isomorphism is the key tenet in the institutional theory (Turkulainen *et al.*, 2017). The term *isomorphism* was firstly introduced by DiMaggio and Powell (1983) to refer to the empirical evidence that organisations are increasingly similar in structures, processes and practices as conformity to institutional rationalised myths. Institutionalists argue that rational actors are inclined to make their organisations increasingly similar to those of their peers in the same field (DiMaggio and Powell, 1983), and therefore contribute to the diffusion of organisational practices (McGovern *et al.*, 2017).

There are two variants of institutional theory: sociological and economic (Kauppi, 2013; Turkulainen et al., 2017). The sociological variant is rooted in the seminal work conducted by Meyer and Rowan (1977) and DiMaggio and Powell (1983) to explain why, over time, firms in the same field adopt the same strategies, structures, and processes without obvious economic returns. The economic variant, on the other hand, is grounded in Haunschild and Miner (1997), who justified corporate similarities that are driven by profit-seeking behaviour, also labelled as 'efficiency'. Surprisingly, although the economic variant has been found valid in explaining managerial actions (Ordanini *et al.*, 2008), academic interest in this variant is often overshadowed by sociological one (Turkulainen et al., 2017). Figure 6 adopted in the study of Kauppi (2013) explicated the underlying tenets of the two variants and a shared concept of uncertainty. The insights into sociological and economic variants as well as uncertainty will be discussed below.

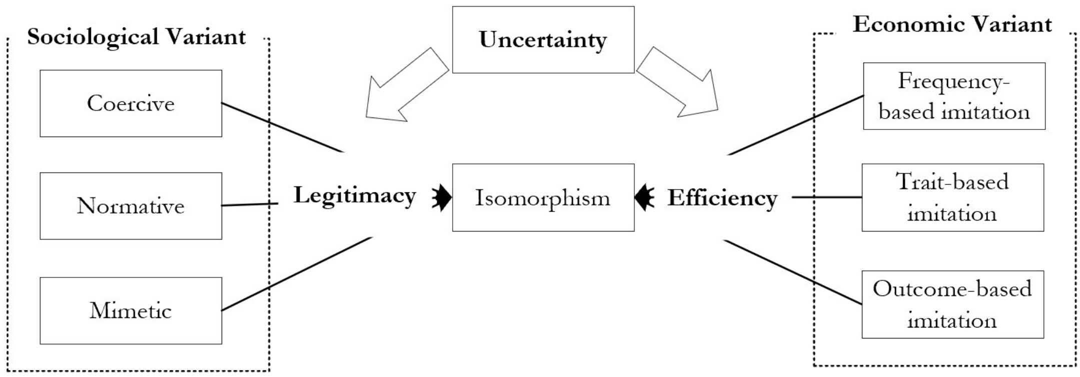


Figure 6: Social and economic variants of institutional theory (adopted from Kauppi, 2013)

2.5.2.3 The sociological variant of the institutional theory

The sociological variant embraces the concept of isomorphism driven by the desire to enhance legitimacy (DiMaggio and Powell, 1983), wherein managerial decision-making shifts its focus from profit-seeking to legitimacy (Gopal and Gao, 2009). It is argued that to survive and thrive in the environment, organisations need more than just tangible resources and technical information; they also need to be socially accepted and credible (Scott *et al.*, 2000). In other words, they need to be legitimate. This is when the *legitimacy* concept kicks in. Legitimacy is defined as "*a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions."* (Suchman, 1995, p. 574). This existence of this desire to be viewed as 'legitimate' (i.e. proper or appropriate) in this environment incentivises organisations in the same field to adopt similar processes without obvious economic returns; over time, this ushers isomorphism (Suchman, 1995; Scott, 2014).

DiMaggio and Powell (1983) elaborated three isomorphism mechanisms (i) *coercive pressure*, which derives from regulatory influence and legitimacy issues; (ii) *normative pressure*, which stems from professionalism; and (iii) *mimetic pressure*, which occurs in response to uncertainty and sees firms emulating others perceived as rational, legitimate, or successful. First, coercive pressure is exerted by formal and informal regulations, enforcement capability, and by the awards issued and sanctions imposed by a legal authority or external constituent upon which an organisation depends (DiMaggio and Powell, 1983). Firms adopt certain behaviours for the fear of being sanctioned by authority or punished by a means of technical barriers by other powerful actors upon which they depend. Second, normative pressure consists of norms and values. It arises from professionalism through either education or the growth of professional networks.

Third, mimetic isomorphism arises in response to uncertainty. The greater uncertainty between means and ends, the greater the extent to which firms model themselves after those of their counterparts they perceive to be successful (DiMaggio and Powell, 1983). It is rooted in anxiety, exacerbated by uncertainty, linked to the desire to avoid having to reinvent the wheel, or to face first-mover risk, which might therefore lead to suboptimal results (Miemczyk, 2008). The strength of these three pillars in resisting change and preserving stability is formidable.

The sociological variant is also referred to as 'neo-institutional theory' to drift away from the old institutional theory in the 19th and early 20th centuries associated with the works of prominent scholars such as Max Weber, Cooley and Mead, to Veblen and Commons (Scott, 2014). The old institutional theory was criticised for being overly descriptive, normative, and legalistic, as stated by Coase (1984, p. 230), "*without a theory they had nothing to pass on except a mass of descriptive material waiting for a theory, or a fire.*" The isomorphism mechanism specified in the neo-institutional theory has overcome these limitations of the old institutional theory and revitalised the academic interests in the application of the institutional theory in multiple disciplines beyond social science. In operations and supply chain management literature, this variant has been successfully employed to explain the diffusion of sustainable practices (see Dubey *et al.*, 2015; Silvestre, 2015; Lucas and Noordewier, 2016; Liu *et al.*, 2018).

2.5.2.4 The economic variant of the institutional theory

The economic variant, grounded in Haunschild and Miner (1997), explains the isomorphism driven by the efficiency forces. In other words, it argues that firms tend to adopt similar efficient practices such as those conducive to reducing costs or increasing productivity. Hence, the economic variant adds efficiency-related factors to the causes of isomorphism and puts forward three distinct modes of imitation: frequency, trait, and outcome-based.

First, frequency-based imitation refers to the mimicking of those actions that have been undertaken by a large number of firms. This is strongly supported by substantial empirical evidence that shows how, when a critical mass of adopters enact a practice, its legitimacy is enhanced or it is endowed with 'taken-for-granted' status (March, 1981; Zucker, 1987). It can also be attributed to a technical rationale, as the frequency of use serves as a valid proxy indicator of technical value, which in turn leads to more adoptions (Rogers, 2010). *Second*, trait-based imitation involves the adoption of those practices espoused by large or successful firms in the same field. Firms tend to measure themselves against high-status, prestigious firms that act as market leaders. *Third*, outcome-based imitation entails copying those actions that appear to provide salient positive outcomes. This type of imitation is driven neither by the critical mass nor the trait of a large or successful firm, but purely by the apparent outcomes brought about by adoption (Haunschild and Miner, 1997). Firms observe the outcomes of the actions undertaken by others and imitate those they perceive to have generated favourable outcomes, avoiding those that appear to have produced negative ones. In the shortest description, frequency-based imitation is strongly linked to legitimacy and taken-for-grantedness, influential traits are often presumably associated with status, while the outcomes are closely bonded with technically efficiency (Haunschild and Miner, 1997). The frequency and trait-based forms of imitation are attributed to social factors, whereas outcome-based imitation leans towards techno-eco ones.

As mentioned earlier, research interests in the socio-variants eclipse those in economic one, exemplified by the fact that much of the work in the use of institutional theory in the area of supply chain management and sustainability is still narrowed in the concepts of *isomorphism and legitimacy* (Greenwood, 2008). This limitation is largely attributed to the fact that sustainability is seen as a symbolic adoption as a response to regulatory and social pressure rather than by economic motive (Glover et al., 2014). The integration of both economic and sociological variants can contribute to providing an analytical framework for the research phenomenon from the angle of more extended and contemporary institution theory.

2.5.2.5 Uncertainty

Two variants share a common element of uncertainty that can arise from the supply, demand, technology, and process sources (Kauppi, 2013). The greater the uncertainty between means and ends, the greater the extent to which firms model themselves on the counterparts they perceive to be rational, legitimate, or successful (DiMaggio and Powell, 1983). This imitation is rooted in anxiety that is exacerbated by uncertainty and linked to the desire to avoid having to reinvent the wheel or to face first-mover risk, which might, therefore, lead to suboptimal results (Miemczyk, 2008). Kauppi (2013) argued that when experiencing deep uncertainty, firms are less likely to adopt a practice by efficiency pressure, but more by legitimacy force. In other words, regulatory, social and cognitive factors (legitimacy group) have a stronger influence than economic and technological factors (efficiency group) in the presence of certainty.

2.5.3 Gaps in the institutional theory

To our knowledge, no empirical investigation has hitherto been conducted on the possible congruence of the socio-eco variants. Because the circular economy realistically facilitates the harmonisation of economic development (efficiency) and environmental protection (legitimacy) (Ghisellini *et al.*, 2016; Murray *et al.*, 2017; Merli *et al.*, 2018), the circular economy offers a best-fit empirical case for integrated institutional theory.

Further, institutional theory, albeit reaching its adolescence in the organisational and sociology research domains (Scott, 1987), remains embryonic in operations and supply chain management (OSCM) (Kauppi, 2013; Glover, 2014). The attention in the extant literature had primarily been constrained to green practices/sustainability (e.g. Zailani et al., 2012, Tachizawa et al., 2015; Liu et al., 2018; Li et al., 2019), quality improvement practices (e.g. six-sigma in Braunscheidel, et al., 2011), innovation (Azadegan et al., 2013; McGovern et al., 2017), or supply chain integration (Turkulainen et al., 2017). Meanwhile, prior studies have merely acknowledged the 'myth' of compliance due to political-social pressures and have overlooked its economic variant (Kauppi, 2013). This study, therefore, contributes to advancing the explanatory power of institutional theory in the circular economy by providing empirical evidence. We argue that the extended institutional perspective, which considers all external constituents, is best suited to be our theoretical lens, without the need for any additional qualifier.

Because circular economy facilitates the dual attainment of economic and environmental value, we labelled circular economy logic as a legitimacy-embedded efficiency. The introduction of institutional logic also underlines the fundamental differences between circular economy and green SCM adoptions. Whereas the latter aim at enhancing firm legitimacy potentially at the expense of efficiency, the circular economy offers a good balance between the two. This also justifies why the purely sociological stream of research has become popular in green SCM studies (Liu *et al.*, 2018).

The frequency and trait-based forms of imitation are attributed to technological factors, whereas outcome-based imitation leans towards economic factors. Thus, the extended institutional theory gives rise to four distinct influencing factors: (i) *regulatory,* (ii) *social,* (iii) *cognitive,* (iv) *economic,* and (v) *technological*. Whereas the first three groups aim at enhancing the legitimacy of the adopted practice, the last two groups contribute to improving its efficiency.

2.6 Summary of gaps in the literature

The previous reviews of food by-product management, the circular economy, and institutional theory literature have underscored four significant gaps that this study seeks to fill in. These gaps are condensed as follows:

First, despite an overwhelming number of studies on food waste valorisation under the emerging circular economy landscape, the translation of the circular economy principles in the food by-product management remains ambiguous*.* This is the first effort to explicitly introduce how the circular economy can be implemented in the management of food by-products by three principles, namely, the production of high-value biomaterials, cascading biorefinery, and green technology.

Second, a lack of empirical evidence on the food by-products valorisation under the circular economy landscape. The majority of literature employs the methodology of systematic reviews, laboratory or pilot-scale experiments, or opinion/commentary works. This is explained by a small number of firms that are familiar with and genuinely capture the essence of the circular economy paradigm. This study is among a few endeavours to supplement the practical case studies to advance the knowledge of this nascent field.

Third, the identification of the drivers of and barriers to the circular transition in food by-products management is an underexplored topic while no consistent and useful way is captured to classify these factors. Due to the novelty of the circular economy and the context-laden nature of the investigation of drivers and barriers in the sector, it is imperative to investigate the nexus of driver-barrier practice for the success of the circular economy transition. While drivers should be leveraged, practitioners and policymakers should be wary of the barriers and come up with mitigation initiatives. This study not only contributes to identifying the list of influencing factors facilitating and hindering the circular economy implementation in the food by-product valorisation but also proposes a novel theory-based classification method to overcome the classification issue in extant literature.

Fourth, institutional theory has been adopted in its simplest form which is in its sociological variant to explain the homogeneity among firms in the circular economy transition. The theoretical power is therefore limitedly leveraged. In order to keep up with the theoretical development in a broader literature, this thesis has supplemented a discourse of institutional logics to elucidate the heterogeneity among firms in a transition period as the result of the shift in dominant logic, then offering a novel way to classify the identified drivers and barriers by integrating two variants of institutional theory (sociological and economic variants). In other words, this study goes beyond the use of sociological variant, and for the first time, integrates two variants of the institutional theory that contains both legitimacy- and efficiency-related factors in a single analytical framework.

In summary, this chapter has critically reviewed and analysed both academic and grey literature relevant to the scope of this thesis consisting of food waste management and circular economy literature. The review places an emphasis on the conceptual development and typology, the circular economy implementation in food by-product management, and associated drivers and barriers in order to draw out four knowledge gaps that motivate this thesis to search for the answers. The next chapter (Chapter 3) will describe the research philosophy, research approach, research strategies and other relevant methodological aspects of this thesis.

Chapter 3 Research method

This chapter details the research method of this thesis, which is structured following the research onion (Saunders *et al.*, 2019, p. 30). As research methodology often involves multiple decisions from high-level and philosophical to tactical and practical ones, research onion is a useful way to enable holistic thinking of methodology. From the outer layers inwards, five layers of the research onion will be discussed: research philosophy, research approach, research strategies, data collection and data analysis (Saunders *et al.*, 2019). In addition, research quality assurance and ethical consideration are also presented. Specifically, the first section, Section 3.1, succinctly depicts popular philosophical stances and research paradigms in business research, before shedding light on the philosophical stance selected in this thesis that fit the research topic and nature of the investigation. Then, the research approach is discussed in Section 3.2 to justify the direction of reasoning undertaken in this study. The third section, Section 3.3, encapsulates different research strategies and illuminates the suitability of the multiple case design in the achievement of the predefined objectives. Next, the data collection and analysis are presented in Section 3.4. This is followed by the discussion of research quality (Section 3.5) and ethical safeguards (section 3.6). The final section, Section 3.7, offers a chapter summary.

3.1 Research philosophy

Research philosophy refers to "*a system of beliefs and assumptions about the development of knowledge*" (Saunders *et al.*, 2019, p. 130). Research philosophy, therefore, contains assumptions about how the researchers view the world, and these assumptions shape entire aspects of the research as well as enable the comparison of different philosophies. Three major assumptions are ontological, epistemological, and axiological assumptions. *Ontology* concerns researchers' assumptions about the nature of reality. It determines how researchers view the world and choose what to study. *Epistemology* refers to the researcher's assumptions about knowledge (Crotty, 1998), and centres on the questions of what is seen as acceptable and legitimate knowledge, and how adequacy and legitimacy of knowledge can be certified (Burrell and Morgan, 2017). Epistemological stance allows the researcher to determine whether numerical data, textual and visual data, facts, opinions, or narratives and stories can be constituted as 'legitimate' knowledge. *Axiology* focuses on the role of values and ethics during the research process – how researchers deal with their own values and also with those of our research participants. Axiological stance enables researchers to decide whether they should let their own values shape the research, and to what extent they consider the impacts of their own values as a positive thing, as well as how to deal with the values of participants. In short, three philosophical assumptions embrace those concerning the nature of realities (ontology), human knowledge (epistemology), and the role of values and ethics (axiology).

To ensure a strong research design, researchers must explore and understand their own research philosophy by reflecting on their own beliefs, values and actions to derive a well-organized and consistent set of assumptions (Haynes, 2012) and shaping their relationship between their philosophical positions and how they conduct the research, thereby enhancing research quality and boosting researchers' creativity (Alvesson and Sandberga, 2009). In this regard, the choice of research philosophy affects all steps of the research from the choice of research topics, the formation of research questions and objectives, the approach to theoretical development, and the choice of research methodology to research outcomes (Alvesson and Sandberga, 2009; Mir *et al.*, 2015). Hence, it is important to be familiarised with five major research philosophies in business before justifying the alternative that has been adopted in this thesis.

3.1.1 Five philosophies

In this part, the underpinnings of five main research philosophies in business and management (positivism, critical realism, interpretivism, postmodernism and pragmatism) will be examined in depth with respect to their ontology, epistemology, axiology, and typical method used.

Table 10: Comparison of five popular research philosophies (Adapted from Saunders et al., (2019))

	Ontology (what is the nature of reality)	**Epistemology (what constitutes acceptable knowledge)**	**Axiology (views on the role of values and ethics)**	**Typical Methods**
Posititivism (naïve/ direct realism)	One universal truth/reality	Observable and measurable facts with law-like generalisations	Value-free Researcher has an objective stance	Deductive quantitative on a large sample.
Critical Realism	Stratified reality (the empirical, the actual and the real)	Epistemological relativism Facts are socially constructed	Value-laden with acknowledgement of researcher's bias	Any methods to analyse retroductive and historically situated problems
Interpretivism	Socially constructed reality	Narratives, stories perceptions, interpretations are legitimate knowledge	Value-bound to researcher. Interpretation of researcher is the key	Inductive/ abductive Small sample, in-depth interviews
Postmodernism	Socially constructed reality through power relations; some realities are dominated or silenced by others	'Knowledge' or 'truth' is determined by dominant ideologies; a need to challenge dominant views to bring out silenced and oppressed ones	Value-constituted, influenced by the power relation between researcher and participants	In-depth investigations of anomalies, silences, absences
Pragmatism	Reality is the practical	'Knowledge' or 'truth' are those	Value-driven research is instigated	Depending on the research

	consequences of ideas	that enable successfully action	and sustained by researchers.	problem and questions, different methods are used.

3.1.1.1 Positivism

Positivism is an objectivist philosophy, which refers to the philosophical stance of natural scientists and often looks for causal relationships in data to deliver law-like generalisations to give explanations and predict behaviours and events. It emerged in the early 20th century in the works of Francis Bacon, Auguste Comte and a group of philosophers and scientists known as the Vienna Circle.

In positivism, the *ontological* stance is only one reality existing as an analogy to physical objects or natural phenomena. *Epistemologically*, the researcher often uses a scientific method to produce pure data and observable and measurable facts that are free from human interpretation and bias (Crotty, 1998). The generated knowledge is unambiguous and accurate. *Axiologically,* positivists carry out research in a value-free manner to stay neutral and detached from research and data.

Positivists often start with an existing theory to formulate hypotheses, then gather the facts for hypothesis testing that leads to further theory development. A popular method used by the positivists is a statistical analysis to facilitate replication, e.g. internet questionnaires, but some positivists may seek to quantify qualitative data by testing the hypothesis on data originally collected in in-depth interviews.

3.1.1.2 Critical realism

Critical realists believe in the existence of a single reality but this reality might not be accessible to our observations. They start with the observed events and reason backwards to identify the underlying reality that gives rise to such events. Critical realism is introduced in the late 20th century by Roy Bhaskar as a response to the critiques of positivism and postmodernism. Critical realism lies in a middle ground between positivist and postmodernism (Reed, 2005).

Stratified ontology is the most significant philosophical consideration of critical realists, which includes: the Actual, the Empirical and the Real (Fleetwood, 2005). The 'Real' refers to the underlying causes of an event. The 'Actual' is the events/non-events caused by the Real that may or may not be observed. The 'Empirical' is the events that are observed, sensed or experienced by researchers. While the Real is external and independent, it might not be directly accessible through human observation and knowledge. Critical realists argued that what researchers observe (the 'Empirical') are just the manifestations of the things in the real world rather than the actual versions. *Epistemologically,* critical realists adopt an epistemological relativism, which implies that theories and concepts cannot convey complete and certain knowledge. Knowledge is thus argued to be historically situated and solely a result of its time and specific to it (Bhaskar, 2010). To seek knowledge, critical realists need to first sense what they experience, and then go through a mental backward reasoning process to identify the inherent reality that might have triggered it. Causality cannot be reduced to statistical quantifications (Reed, 2005). *Axiologically,* critical realists recognise the value-laden of researchers in the generation of knowledge because social facts are social constructions agreed upon by the social actors involved rather than existing independently (Bhaskar, 2010). As such, researchers should acknowledge the possible influence of their own socio-cultural backgrounds and experiences on the research in order to minimise bias.

In terms of the dominant research method, critical realists often seek to analyse the historical endurance and/or evolution of social and organisational structures (Reed, 2005). Further, critical realists acknowledge the existence of a single reality but they are considered to be less objectivist than positivists, and they embrace epistemological relativism so they can adopt both subjectivist and objectivist research methods (Reed, 2005).

3.1.1.3 Interpretivism

Like critical realism, interpretivism distinguishes the study of a social phenomenon from a physical phenomenon because of the different cultural backgrounds and circumstances involved in the former. The rich insights of the social phenomenon are lost if its complexity is reduced to the so-called law-like generalisations that apply to everybody. Interpretivism emerges in early- and mid-20th-century Europe by German, French and English thinkers (Crotty, 1998).

Ontologically, social phenomenon exhibits multiple meanings, interpretations and realities; thus, interpretivists reject both objective and stratified ontology but believe in multiple and relative reality that is conceived through the language, perceptions and behaviours of social actors. *Epistemologically*, interpretivists embrace epistemological realism where the acceptable knowledge can be opinions, narratives, interpretations, and perceptions of social actors in the reflection of social realities. *Axiologically*, interpretivists seek to include the interdependence and mutual interaction of participants and researchers in the research; hence, the researchers' values and beliefs are important in their interpretations of the social world. Interpretivists should adopt an empathetic stance as it is difficult for them to go into the social world of participants and comprehend that world from their own viewpoint.

3.1.1.4 Post-modernism

Postmodernism believes in the co-existence of multiple realities, but some are silenced or marginalised while others are dominant. This is due to the role of language and power relations.

The objective of postmodernists is to find out the hidden perspective and give voice to marginalised reality. It arose in the late 20th century with the work of several French philosophers such as Jean-François Lyotard, Jacques Derrida, and Michel Foucault.

The *ontological* stance of postmodernism is that multiple realities exist, and some are dominant due to the power relations that sustain them and oppress others. Hence, the description of the world cannot be validated by any abstract means. Rather, the right is purely the dominant reality that is decided collectively by power relations and by the dominant ideologies in certain contexts at a specific point in time. Other suppressed realities might be just as valuable in creating alternative truths. *Epistemologically*, postmodernists aim to challenge the dominant reality – the widely accepted truth – and give voice to alternative marginalised views that have been suppressed by that truth. Postmodernists seek to expose the instabilities and absences within the data to unravel power relations. *Axiologically*, researchers should discuss their own values and beliefs because of the existence of power relations between researchers and research subjects in the creation of knowledge. Hence, postmodernist axiology is radically reflexive about their thoughts and works (Cunliffe, 2003).

3.1.1.5 Pragmatism

Pragmatism establishes that concepts are only pertinent when they engender action (Kelemen and Rumens, 2008). It attempts to reconcile both positivism (objectivism) and interpretivism (subjectivism) (Elkjaer and Simpson, 2011). It considers the findings are not abstract but they play an instrumental role in actions and thinking, and regarding their practical outcomes in particular situations. In other words, pragmatism deals with a problem itself rather than theoretical concerns. Pragmatism emerged in the late 19th and early 20th centuries through the work of American philosophers Charles Pierce, William James and John Dewey.

Ontologically, pragmatists assume that reality is constantly renegotiated, debated, interpreted, and hence the argument of the existence of single versus multiple realities, also known as an ontological assumption, is less pertinent to the pragmatist. *Epistemologically*, pragmatists view acceptable knowledge from practical effects that allow actions to be implemented successfully. The *axiology* stance of pragmatists emphasises the beliefs of the researchers that shape and are shaped along the research process.

For these reasons, pragmatists can employ a range of research strategies depending on the nature of the research. For them, the best method(s) is the one that enables the collection of credible, reliable, well-established and pertinent data to answer the research questions (Morgan, 2007; Kelemen and Rumens, 2008).

3.1.2 Rationales for an interpretivism research paradigm

As highlighted above, the exploration of research philosophy is a crucial step in the PhD research design. It influences the researchers' decisions regarding the research topic, research questions, research approach, methodology, data collection and analysis methods, as well as findings. To make an informed choice of the suitable research philosophy, the researcher conducted the Heightening your Awareness of your Research Philosophy (HARP test) created by Bristow and Saunders (Saunders *et al.*, 2019, pp. 161-164). This test enabled the researcher to reflect on five research philosophies in order to explore my own philosophical standpoint. The result of the HARP test indicated the philosophical preference of the researcher as follows: interpretivism (19 points), pragmatism (12 points), postmodernism (11 points), critical realism (11 points) and positivism (10 points). Accordingly, the researcher leans toward embracing an interpretivism philosophical stance. This choice of philosophical stance is further substantiated by the aim of this research to build rather than test a theory. Hence, the researcher negates the universal truth ontological assumption of positivism and the stratified reality assumption of critical realism. While supporting a socially constructed reality, the researcher trusts the existence of reality and denies the ontological assumption of pragmatism. Finally, this study does not examine power relations or bring about the silenced or marginal reality as the aim of postmodernists. Taken together, interpretivism offers the best fit philosophical stance for this study, and the researcher will specify the details of interpretivism's philosophical stance below.

The researcher believes that the nature of reality (*ontology*) is neither objective nor external, it is instead socially constructed and varies in accordance with opinions, perceptions, experiences and interpretations of the actors and contexts. In such an intricate and socially constructed reality, the role of culture, language and personal experiences are crucial. Besides the personal belief, this relativist ontology is highly pertinent to the objectives and the context of this thesis. First, the relativist orientation fits well with the study's overarching objective to deepen the understanding of the rather ambiguous and multidimensional phenomena, the circular economy implementation practices in food by-product management (Silverman, 2016). Second, the relativist ontology highlights the significance of the context in which the circular economy in food waste management has been implemented in the UK. In this regard, the uniqueness in the contextual characteristics of the UK, including social norms, political, cultural and economic factors, are well captured and accentuated. This enables the researcher to grasp an in-depth and context relative analysis of the nature of the implementation strategies preferred and how various stakeholders perceive the accompanied drivers and barriers.

As regards *epistemology*, the acceptable knowledge in this study includes opinions, narratives and perceptions of key stakeholders in the reflection of social realities that embrace the practices and influencers of food by-product management in the circular transition. Also, the interpretations of the circular economy paradigm and the theoretical lens of the institutional theory are counted as the acceptable knowledge of the realities.

In line with the value-bound *axiology* of interpretivism, the researcher is part and parcel of the inquiry being conducted. As opposed to the positivist/realist assumption of detachment and independence in the role of the researcher during the research process, interpretivists espouse the necessity of the direct participation and interactions of the researcher with the research objects in the research process to derive an intimate and deeper understanding of socially-constructed reality (Guba and Lincoln, 2005; Neuman and Robson, 2014). Bearing this role and position of the researcher in mind, the researcher has tried to interact with different groups of informants in different cases using interviews and observations. Such interactions give more opportunity for the researcher to capture an insider and intimate perspective.

Finally, the researcher while upholding the value of the interpretivism paradigm acknowledges its certain shortcomings. The major shortcoming associated with relativist ontology is the failure to generalise findings. Due to taking subjective experiences and perceptions of multiple stakeholders from multiple cases in the unique setting of the UK in the operationalisation of the circular economy in food by-product management, some of the findings, such as drivers and barriers, might not be practically applicable to other contexts. The second limitation comes from subjective epistemology and value-bound axiology, which might lead to the potential risks of biased opinions and judgements from limited knowledge and personal interests. Necessary measures have been taken to mitigate this bias limitation and the details are presented in Section 3.5 of this Chapter. Following the interpretivism research paradigm, the next section will discuss the research approach taken in this study.

3.2 Research approach

3.2.1 Three research approaches

This section examines the research approach, or the researcher's direction of reasoning, in making inferences in this thesis. Researchers in empirical studies often employ three directions of reasoning – induction, deduction and abduction – to process from grounds to claims, from premises to conclusions in a sound manner (Toulmin, 2003; Mantere and Ketokivi, 2013; Ketokivi and Choi, 2014). The deductive approach is often connected with positivism philosophy, whereas inductive and abductive are linked to interpretivism philosophy (Bell *et al.*, 2018). The underlying features of these approaches are presented below:

In deductive reasoning, the researcher deduces a hypothesis based on the knowledge of a specific domain and of related theoretical underpinning (Bell *et al.*, 2018), and then designs quantifiable variables to test the hypothesis. Put in simple, the researcher often starts with a theory or a hypothesis that is derived from a theory before testing it on large scale to generalise findings (Collis and Hussey, 2013). As such, common research methods for the deductive approach are questionnaires and surveys.

Inductive reasoning follows an opposite direction that aims at theory building; hence, a theory is an outcome, not a starting point. The researcher first grasps the understanding of the research domain, and then draws the interferences or develops a theory from it. This approach is largely based upon qualitative data, so it is less structured in data collection and analysis compared to the deductive approach (Collis and Hussey, 2013). This also encounters the bias problem from both researchers and participants while the results heavily rely on subjective inferences of the researcher. Findings are therefore less generalisable. Bearing that in mind, the researcher who employs this approach might not aim at generalisation but the development of a rich and deep understanding of a complex phenomenon with ambiguous boundaries in its actual context where a testable hypothesis is impossible to be drawn (Easterby-Smith *et al.*, 2012).

In abductive reasoning, researchers "move back and forth between induction and deduction—first converting observations into theories and then assessing those theories through action" (Morgan, 2007, p. 71). Abduction is suitable for the use of multiple theoretical lenses to facilitate iterations between empirical data and theory in order to explain particular phenomena (Dubois and Gadde, 2002;2014). The iterative process between theoretical construct and empirical evidence is the cornerstone of abductive reasoning (Eriksson and Engström, 2021), which is acknowledged by Plakoyiannaki and Budhwar (2021, p. 4): "expectations are shaped by preconceptions, worldviews and beliefs rooted in researchers' experiences and exposure to theories".

In short, deduction is an inference to a particular case, inductive is an inference to a generalisation, and abduction is an inference to an explanation. Hence, researchers predict, confirm and refute through deduction, generalise through inductive and theorise through abduction (Mantere and Ketokivi, 2013).

3.2.2 Rationales for the abductive reasoning approach

This thesis adopts an abductive reasoning, rather than a deductive or inductive approach, for several reasons. *First*, owing to a dearth of existing knowledge and empirical evidence, and given the complex and ambiguous boundaries of the circular economy phenomenon, it was impossible to design a testable hypothesis as well as test it on a large sample. Hence, deduction that strictly advocates the reliance on the logic of theory and hypothesis testing (Mantere and Ketokivi, 2013; Bell *et al.*, 2018), cannot be adopted here. *Second*, this study engages with a pre-existing theory – the institutional theory – rather than develop a new theory as required by inductive approach (Dubois and Gadde, 2002). Hence, abductive rather than inductive was favoured. Further, while both induction and abduction allow researcher to collect qualitative rich data that provides a foundation for the emergence of a new abstract concept and increase the prospects of exploring surprising insights in the coded data and to generate a flexible structure that can be easily amended or adjusted as the research progressed (Creswell, 2007), abduction evades the main issue associated with inductive reasoning in its inability to develop a new theory, regardless of the size and depth of empirical data (Creswell *et al.*, 2011). *Third*, abductive reasoning fits well with the objective of identifying causal mechanism that best explains social events or phenomena (Fletcher, 2017). This study focuses on unravelling the puzzling mystery as to how and why practitioners engage in circular food by-product management. Thus, this involves detecting conditions that would make the phenomenon less puzzling and therefore 'easier' or more logical to grasp, thus locating the best explanation plausible to explain the phenomenon (Mantere and Ketokivi, 2013).

Aligned with abductive reasoning, the study draws on existing concepts related to institutional pressures and institutional logic whilst also building on inductive findings from actual experiences and perceptions of actors in the cases to explore the nexus between drivers, barriers and practices of the circular food by-product management. The research is characterised by the compilation of qualitative data and the researcher has an integral role in the research process to make subjective inferences. Finally, to overcome the generalisable limitation of the abductive reasoning approach, a range of measures have been taken to assure the overall research quality, which will be discussed in Section 3.5.

3.3 Research strategies

3.3.1 Research methods

A number of different research methods can be used in the business management discipline and social sciences. Table 11 provides a guideline for the researchers in the selection of suitable research methods based on research objectives and research questions.

As the literature indicates little prior knowledge available in this specific research stream, this study is exploratory by nature. In addition, given it seeks to answer how and why questions, three qualitative research strategies can be appropriate: experiment, case study, and participant observation (Yin, 2014; Collis and Hussey, 2009; Bryman and Bell, 2015). A case study research design is chosen in this thesis for three reasons. First, the researcher did not want to influence or exert control on the firms' working environment at any stage of the research, which rules out participant observation and experiment. Second, case studies are well suited for the study of emergent and multifaceted phenomena—such as the circular economy—because of their interpretative information richness that may not be achieved by means of a quantitative method like surveys (Baxter and Jack, 2008; Barratt et al., 2011). Third, a case study demonstrates its suitability to construct new operational management theories from concrete and context-dependent knowledge (Voss et al., 2002). Taken together, a case study offers an ideal method for conducting an exploratory study and answering the research questions in this thesis. In the section that follows, the researcher will focus on the case study research in-depth.

Table 11: Selection of research strategies based on research objectives and questions (Adapted from Marshall and Rossman (2014))

Objective	Questions	Research strategies
Exploration	How, why	Experiment, Case study, Participant observation
	How often, how much, how many, who, what, where	Survey, Secondary data analysis
Explanation	How, why	Experiment, Case study, Grounded theory, Participant observation, Ethnography, Case survey
Description	Who, what, where	Experiment, Case study, Grounded theory, Participant observation, Ethnography, Case survey
	How much, how many	Survey, Longitudinal, Secondary data analysis
Prediction	Who, what, where	Experiment, Case study, Grounded theory, Participant observation, Ethnography, Case survey
	Who, what, where, how much, how many	Survey, Longitudinal, Secondary data analysis

3.3.2 Case study

Case study is preferred when the research seeks to answer 'when, how, and why' questions, when the researcher has no or little control over the phenomenon, as well as when the phenomenon under investigation is contemporary in a real-life situation (Yin, 2013). A case study design is defined as "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*" (Yin, 2013, p. 16).

In operations management studies, case study research is a useful means of examining new phenomena and practices in order to contribute to theoretical development (Voss *et al.*, 2002). Case study research provides rich data on social processes that enable researchers to delve into the events, experiences, relationships and processes in a specific context (Piekkari et al. 2010; Vissak, 2010; Woodside and Wilson, 2003). Case study research is also favoured for its flexibility and high adaptability because the investigator can adapt the research's directions to the emergence of new data during the data collection process. For these benefits, a case study has now been seen as a standalone methodology rather than a data collection technique (Yin, 2014; Eisenhardt, 1989; Glaser and Strauss, 1967). Under this methodology, multiple data collection techniques can be applied, including interviews, documents and observations.

Growing scholarly interests has been paid to case research since the seminal work of Eisenhardt (1989) but their adoptions come in a variety of forms and manifested in multiple theoretical and epistemological premises Ketokivi and Choi (2014). In an effort to capture this heterogeneity, Ketokivi and Choi (2014) identified three distinct approaches to case study research: theory generation, theory testing, and theory elaboration (Table 12). Although all three approaches contribute to theoretical formulation via the interaction between a general theory and the empirical context, the level of emphasis on theory or empirics varies. Specifically, theory generation seeks to unravel whether the data in an empirical context can lead to more theoretical insight and potentially lead to a new theory generation, whereas theory testing aims to test whether a priori theoretical hypotheses are context-specific. Theory elaboration considers the possibility of contextualising a prior theory using empirical data. Given research objectives, this thesis followed the theory elaboration approach to case research where the researcher seeks to challenge the logic of the general theory and reconcile the general from the theory and the particular from an idiosyncratic empirical context.

Table 12: Three methodological approaches to case research (Adapted from Ketokivi and Choi (2014))

Types	Description
Theory generation	Follows inductive reasoning where researchers often employ grounded theory in a novel and unfamiliar context that might not be fully explained by a general theory.
Theory testing	Follows deductive reasoning where researchers often put a theory to a test via an a priori theoretical hypothesis.
Theory elaboration	Follows abductive reasoning where researchers remain open to unanticipated findings and the possibility of refining a general theory. This involves modifying the general theory to reconcile it with contextual idiosyncrasies.

A case study design is often divided into two types: single case and multiple case design. The Next section sheds light on the differences between single versus multiple case studies to justify why multiple cases provide the best fit for this thesis.

3.3.3 Single versus multiple cases

Once choosing a case design, the researcher must make a decision between a single case and multiple cases. Although it is widely claimed that single and multiple case design offers their own merits and are acceptable and valid (Benbasat *et al.*, 1987; Ellram, 1996; Yin, 2013), the choice is largely decided by the research objectives.

A single case is normally chosen when it signifies a critical case for theory testing, it is unique or extreme, or it reflects a revelatory case. A single case adds more depth to the analysis (Voss *et al.*, 2002) and is highly suitable for longitudinal inquiry for rich data on operations within only one firm (Yin, 2013). However, a single case study faces several criticisms, typically, less room for replication and generalisation and the risk of misinterpreting events, overstatement and jumping to conclusions too early (Yin, 2014).

On the other hand, multiple case study is favoured for their strength in replicating a single type of incident in different settings and enabling comparisons suited to elucidate whether any emergent event is just peculiar to a single case or consistently repeated in several cases (Eisenhardt, 1989; Yin, 2013). Hence, it tends to deliver more compelling stories while external validity is enhanced, and overall conclusions are more robust. In addition, while a single case normally aims to explain or test a theory, multiple cases can contribute to theory-building purposes thanks to their theoretical replication and generalisation of the results to offer a rich theoretical framework (Benbasat *et al.*, 1987; Ellram, 1996). Notably, multiple cases can involve the investigations of multiple functions, operations and departments within a single firm; hence the number of cases and the number of firms are not similar (Voss *et al.*, 2002). However, the researcher who goes with the multiple case design might encounter challenges as a result of time and resource constraints (Voss *et al.*, 2002; Woodside and Wilson, 2003; Piekkari *et al.*, 2009). Despite this limitation, multiple-case design is chosen for its merits in delivering more compelling outcomes and contributing to richer theoretical elaborations.

There is no consensus in the literature on what the appropriate number of cases should be. For instance, Eisenhardt Eisenhardt (1989) recommended no more than seven cases for a researcher to mentally process; while six to ten cases were suggested by Ellram (1996) to be a sufficient number to offer sound evidence. Perry (1998) indicated a minimum range of two to four and a maximum range of twelve to fifteen. The recent book of Yin (2019) imposed no hard limit but suggested that data should be collected until saturation. In operations and supply chain management studies, multiple case study articles often employ three to 11 cases. As the suggestions vary in literature (Pagell and Choi, 2009). This article stops at six cases in the UK food supply chain where the researcher reached the saturation point and the limits of the amount of data that can be effectively processed.

This research aims not only to explore the phenomenon of circular innovation in food waste management but also to understand what drove these firms to engage in circular innovations and what hinders their process. Multiple case study was beneficial to gaining broader insights into current practices, associated drivers and barriers by looking at multiple firms. In the next section, the processes of collecting and analysing data will be presented step-by-step.

3.4 Data collection and analysis

3.4.1 Case selection

Case selection is the very first but critical step in the case study research design (Eisenhardt, 1989; Woodside and Wilson, 2003; Dubois and Araujo, 2007). The choices of cases – who, where, when, what, and why to look at – determine how well the research is designed and conducted, and ultimately influences the outcomes of the study. Following a replication logic, cases were selected based on their likelihood of offering theoretical insights that would shed light on the underexplored phenomenon under study and elaborate on the emergent theory (Yin, 2013). This study aimed to elaborate on a theory, not to test it; thus, purposive sampling (not random or stratified sampling) was chosen (Eisenhardt and Graebner, 2007). The choice was based not so much on the uniqueness of the cases but, rather, on their contribution to deepening the exploration of the circular phenomenon and theoretical development. Two criteria for case selection are specified: *(i)* the case must have a manufacturing base in the UK that involves the homogeneous by-products from food sectors; *(ii)* the case must engage in the implementation of the circular by-product management that meets at least one of three specific principles of the circular economy in the food by-product management: (1) production of higher value-added products, (2) cascading biorefinery (3) green technology.

As analysed above, six cases satisfying selection criteria were sampled, which was deemed to be a sufficient number to give a fairly accurate account in a natural setting with an exploratory bent (Eisenhardt, 1989) and to enable the required depth of observation and illumination of any contrasting patterns in the data (Yin, 2013). The details of six cases along with their settings are presented in Table 17 under Chapter 5 of this thesis.

3.4.1.1 Unit of analysis

Specification of the unit of analysis is crucial to delimit the scope of this study. The unit of analysis is the major entity that is analysed in this study (Miles *et al.*, 2018). The unit of analysis sets clear boundaries for the research and reveals which data should be collected and analysed (Collis and Hussey, 2013). In the case study, the unit of analysis can be anything such as a person (such as a manager or an employee with experience in the research of interest), an organisation, a team or a department inside an organisation, a country, or an event (such as a decision, a programme, a process or an organisational change) (Yin, 2013). The selection of the unit of analysis depends on the research objectives, questions, propositions and theoretical contract.

The unit of analysis is sometimes constrained by factors associated with case selection, such as accessibility, resources and time availability. For example, when only certain data can be accessed, or when limited resources and time to support travelling in the data collection process are available, it is more feasible to study a division within a large organisation rather than its entirety. This thesis aims to investigate how the cases implement the valorisations of food by-products in the circular economy landscape; hence, the unit of analysis of the thesis is the implementation process made by the sample cases to valorise food by-products. Other activities that do not fall into this scope are excluded from the data collection and analysis phases. For instance, case A1's main business line is in processing vegetables, which is not the interest of this study so no data in this regard was collected. Similarly, the researcher did not ask A2 about its renting operation to other firms to process the mushroom by-products. In the end, the main value of the unit of analysis is that it allows the researcher to detect commonalities and differences between the perceptions and behaviours of different respondents in the sample cases as well as capture the underlying reasons for these commonalities and differences.

3.4.2 Data collection

Before going into how the data for this study was collected, it is important to emphasise that data collection and data analysis are not two separate and sequential stages; but they are concurrent in an interactive and iterative manner. This facilitates the management of the sheer volume of qualitative data (Eisenhardt, 1989) and allows the necessary adjustments made in the data collection stage (Glaser *et al.*, 1968). As opposed to collecting the data first and analysing data later, the joint collection and analysis of data encourages the researcher to continuously think about the topic under investigation, and contemplate what can be learnt from it and how this case is different from the other (Eisenhardt, 1989).

Data is collected from three main sources: (i) semi-structured interviews; (ii) direct observations; (iii) internal documents, reports, and website information. The use of multiple sources of data, also known as data triangulation, was beneficial in gaining diverse perspectives on circular practices and enhancing data validity, reliability and transferability while reducing the bias of the researcher and the participants (Voss *et al.*, 2002; Yin, 2013). Data triangulation is particularly preferred in the qualitative and case study methods to add richness to the data and reveal discrepancies in the phenomenon under investigation as well as compare observations with interview questions to avoid misinterpretations by the researchers (Yin, 2013; Bell *et al.*, 2018). The relevant aspects of these three data sources will be presented in the following.

3.4.2.1 Interviews

Interviews were the main tool used to gather the data due to their capability to provide a range of perspectives on the topic (Kvale, 1994). A variety of interview methods – structured, semi-structured, unstructured, and group interviews – can be suitable for empirical investigation. Semi-structured interviews are chosen for the following reasons. First, structured interviews are more apt for questionnaire surveys and often appear in the positivism paradigm (Collis and Hussey, 2009). Second, unstructured interviews pose challenges to compare and contrast data because it is difficult to control the scope of the interviews. Third, group interviews are challenging for a single researcher to orchestrate and carry out, particularly for the telephone interviews as the result of the COVID-19 pandemic. Lastly, the literature indicates the suitability of semi-structured interviews for case study design as it offers rich discourse by giving informants flexibility in expressing their opinions in unpredictable ways and enabling the explorations of foreseeable and unforeseeable events, patterns, or particular behaviours (Charmaz, 2014; Corbin and Strauss, 2014; Saunders *et al.*, 2019). In this regard, Bell *et al.* (2018, p. 479) argued that "*if the researcher is beginning the investigation with a fairly clear focus, rather than a very general notion of wanting to do research on a topic, it is likely that the interviews will be semi-structured ones*". Taken together, semi-structured interviews appear to best satisfy all the criteria for this thesis.

In a semi-structured interview, the research starts with an interview protocol that contains a clear list of questions and themes to be discussed in the interview (Doody and Noonan, 2013). An example of interview protocol in this study is presented in Appendix 3. The questions in the interview protocol were aggregated into groups that addressed the key constructs of the study, consisting of the firms' characteristics and attitudes, circular practices and supply chain configurations, and influencing factors (drivers and barriers). Questions are adapted to the progression of each interview and the characteristics of each case (Charmaz, 2014; Corbin and Strauss, 2014). During the interview, there is no need to strictly follow the sequences of the questions and themes (Doody and Noonan, 2013). In addition, the researcher can be flexible to probe and trigger emergent and interesting issues. However, to facilitate the comparison across cases in the analysis phase, all questions on the interview protocol should be asked using similar wordings (Bell *et al.*, 2018). The interviews occurred at the companies' premises, while interviewee anonymity and confidentiality were assured. The transcripts and summaries of the key deliverables were emailed to the interviewees for validation of facts and any misinterpretation of content. An example of a full-length interview transcript is provided in Appendix 5. The respondents were also contacted via email when clarifications or supplementary data were needed.

The data collection stops when the data reaches theoretical saturation, which means that no new theme is emerging, all the discrepancies in the data were resolved, and the already explored themes start repeating (Bell *et al.*, 2018). The literature widely acknowledges no limit imposed governing the number of interviews that should be taken to reach theoretical saturation. To guide the researchers in the number of interviews needed to reach theoretical saturation, Perry (1998) proposed a rule of thumb to be in a range of 20 to 50 interviews. In this study, the researcher carried out the data collection process and reached the saturation level at 24 interviews from six cases (Appendix 4). For each case, the interviews included at least one high-level management team member, one operational manager, and purchasing and sales staff members. The rationales for selecting these respondents are provided in Table 13.

Table 13: Informants and Reasons for their selection

Informants	The rationale for selecting them
Director (can be founder/co-founder)	Mainly to explore how he/she defines and apply the circular economy concept in his/her strategic, tactical and operational decisions.
Operations Manager	To probe the operational aspects inside the factory once the circular innovation is implemented in the food by-product valorisations.
R&D staff or team member of R&D project	To understand the technological aspects of the circular innovation in the food by-product valorisations, particularly in the laboratory phase
Purchasing/Supply Chain Manager	To study how the procurement and inbound logistics are organised and what are associated drivers and barriers
Sales Manager	To investigate the perspective from the market side once the end products are launched to the market, how to find and expand the customer bases.

Source: Created by author.

Note: Exact titles of informants vary from case to case. See Appendix 4 for the exact titles.

3.4.2.2 Observation

The observation of what the respondents do instead of what they say is beneficial to provide additional information about the topic of investigation (Yin, 2013; Silverman, 2016). During the observation process, the researcher acts as a non-participant and overt observer. Non-participant qualitative observations contribute to the enrichment of data by enabling a sense of human and non-human activities and the environment around them, which in turn improve data triangulation (Stake, 1995).

Several shortcomings of observations include a dearth of methodological and procedural rigour, heavy reliance on subjective interpretations, and absence of measures to verify if observations are *real* or just coincidences that occurred by chance (Gummesson, 2007). Hence, the reliance on observation alone is not recommended; instead, observation should be combined with other methods such as interviews and should be recorded in an observation log to safeguard consistency and improve reliability.

After each site visit, the researcher captures her own observation on a piece of paper and then converts this paper into an observation log that looks similar to an interview transcript. The observation file helps to strengthen consistency, credibility and reliability. Table 14 illustrates how observations had been carried out in this study and linked to the relevant research questions. The details of how some of the findings from interviews were triangulated by observations are provided in the analysis chapter.

Table 14: The use of observations in this study

Areas of observation	**Purpose of observations**	**Link to the RQ**
Technology and operations	To evaluate how advanced the technology is, whether it follows chemical, physical or biochemical routes.	RQ1
Supply chain configurations	To see from where and to where as well as how the materials and end-products are shipped. Where they are stored and in which conditions	RQ2 and 3
Input materials	Quality and consistency of the input materials	RQ2 and 3
End products	Different aspects of products: quality, design, packaging.	RQ2 and 3

Source: Created by author

3.4.2.3 Secondary data

The secondary source of data includes the website and articles written about the cases, as well as the internal reports provided by the cases. *First*, all cases under the investigation have websites that contain some background information about the cases. The researchers always referred to the information on the website before conducting the interviews and site visits to adapt the research questions accordingly. In addition, the researcher spent a significant amount of time corroborating data from the public domain written about the cases and their innovative efforts to widen the researcher's perspective about the case and provide further verification. *Second*, internal documents and reports were handed to the researcher for academic purposes in some cases during the site visits. However, some technical information in these documents was not allowed to be published for confidentiality purposes. Also, the researcher was not allowed to take a picture during the site visit. Therefore, this thesis only presents the information that is available in the public domain and in the internal documents that are allowed to share in these cases. Information obtained from these documents was stored and analysed in the within-case and cross-case analysis.

3.4.3 Data analysis

Data from three above-mentioned sources that include interview transcripts with case backgrounds, observation logs, documents and/or other materials were compiled and analysed in this step. As mentioned earlier, data collection and analysis are not sequential but concurrent. The analysis of data in this study is consistent with a three-step qualitative analysis proposed by

Miles *et al.* (2018), which comprises: (i) *Data condensation:* entails selecting, simplifying, abstracting, and transforming the data collected from multiple sources in the data collection phase; (ii) *Data display:* organises and compresses data in a structure that leads to preliminary conclusion and action; (iii) *Conclusion drawing and verification*: identify and interpret common patterns, causal flows, or prepositions from the structure in data display. Conclusions are verified as the research proceeds.

Data condensation often starts with the coding of data where data is condensed into codes or categories. A code is defined as "*a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data*" (Saldaña, 2015, p. 3). These codes then go into a coding frame, which is a hierarchical set of themes used in coding qualitative data (*data display*). From here, conclusions can be drawn and further verified once new codes enter the matrix (*conclusion drawing and verification*). Hence, coding is a central part of qualitative data analysis. Charmaz (2006, p. 14) stated "*the pivotal link between collecting data and developing an emergent theory to explain these data. Through coding, you define what is happening in the data and begin to grapple with what it means*". Two methods of coding are adopted in this study: open coding and axial coding. Open coding starts with skimming through all data to get familiar with the context, then segmenting data into meaningful expressions before assigning tentative codes (open codes) for these expressions. In axial coding, the open codes are refined, grouped and related to each other to identify which one can be subsumed beneath other categories. Axial coding establishes the interrelationship among open codes and organises them into a coding frame (a hierarchical set of themes). This study processed coding in NVIVO – a renowned software for data management with the capability to code, categorise, analyse and draw conclusions (Welsh, 2002; Leech and Onwuegbuzie, 2011; Brandão, 2015). Notably, NVIVO is not only used for coding but also for data management in this study.

The data analysis in multiple case design is divided into two phases: within-case was carried out before cross-case commenced (Miles *et al.*, 2018). The following will capture the essence of each phase.

3.4.3.1 Within-case analysis

The data analysis started with the analysis of the individual case. The within-case analysis aims to describe, comprehend, and explain what has happened in a single and bounded context of a case (Miles *et al.*, 2018). Within-case is proceeded by using an open-coding technique to code the materials for each case.

In open coding, the data were scrutinised paragraph by paragraph to understand the essence of what they expressed; then, conceptual names were assigned to the data. Coding entailed thinking outside the box to avoid the findings being constrained or even stifled by any extant literature or theory (Charmaz, 2014). The initial codes derived in this step were not only abstract but also provisional in order to enable cross-comparisons and subsequent revisions to improve their fitness in representing the data (Charmaz, 2014; Corbin and Strauss, 2014).

For each case, initial codes exist for the context of the case, and they are organised into three themes with respect to the research questions: innovation practice, drivers, and barriers. The details of the initial codes are presented in Section 4 of this study.

3.4.3.2 Cross-case analysis

Following the within-case analysis, the cross-case analysis was conducted to detect any commonalities and variations between patterns across the cases (Eisenhardt, 1989). The cross-case analysis is a method that involves the in-depth examination of similarities and differences across cases with a view to supporting empirical generalisability and theoretical predictions. It enhances the generalisability and transferability of the findings to similar contexts and reassures that the phenomenon or processes – the adoption of circular economy and associated drivers and barriers – in one setting are not entirely idiosyncratic (Miles *et al.*, 2018). The cross-case analysis is performed by means of a pattern matching technique that aims to "*compare an empirically based pattern–that is, one based on the findings from your case study–with a predicted one made before you collected your data*" (Yin, 2013, p.143).

The initial codes derived from individual cases are synthesised, compared and refined before being hierarchically aggregated to enable the emergence of higher-order themes that are similar and different in cross-case analysis (Glaser and Strauss, 1967). Due to the hierarchical structure in organising the code, the researcher labelled the initial code as the first-order codes and higher-order themes as the second-order codes. The first-order data reflected informant transcripts while the second-order codes reflected theory-centric interpretations. The answers to the RQs were then aggregated through the anchors of refined institutional theory and a set of cross-case conclusions was inferred.

3.5 Research quality

Research quality was measured by four criteria introduced in Yin (2013) and made explicit in Table 15. *First*, construct validity refers to the extent to which the measurements taken in the study actually operationalise the concepts or measure the constructs intended to measure. *Second*, internal validity concerns the extent to which a causal relationship can be drawn between two factors by assuring that no other factor can explicate the relationship. *Third*, external validity shows the extent to which the findings can be generalised beyond the research setting. *Finally*, reliability ensures that the same results can be obtained if the later researcher decides to follow the same process specified by the earlier researcher to conduct the study again. Each criterion will be thoroughly discussed below.

Table 15: Assessment of the empirical validity of the case study research/ measures to ensure the reliability of the case study.

Criterion	**Aims from Yin (2013)**	**Applied in this thesis**	**Measures**	**Research phases**
Construct validity	Use valid constructs to measure the concept	Establish a chain of evidence linking the objectives to the protocol, findings, and literature review.	Multiple sources of evidence/ data triangulation. Chain of evidence. Case report reviewed by informants	Data collection Data collection Data analysis
Internal validity	Establish an appropriate causal relationship or make a valid inference	The research built on recognised principles of circular economy and related literature, acting as foundation to identify critical factors and relationships driving behaviours	Pattern matching within and across the cases	Case analysis
External validity	Ensure the analytic generalisation of the findings *(If the exact condition of the case is recreated, the same findings are found)*	Thesis objectives drive the design of the thesis. The theoretical sampling aligned with the scope of the study to create a coherent sample.	Choose an appropriate theory. Select initial RQs with how and why. Theoretical replication logic.	Case design Case design Case design
Reliability	The same results are arrived at if a later researcher follows the same process specified by the earlier one to do the same case again.	A case protocol is developed and validated to ensure reliable results and remove bias or errors.	Case protocol. Retrievable data organisation. Formalised coding.	Data collection Data collection Data analysis

Source: Created by author

3.5.1 Construct validity

Construct validity aims to ensure the concepts are measurable via a specific set of indicators or operational measures while the shortcomings of such measures are acknowledged, and mitigation measures are provided to minimise bias. Construct validity is assured by clearly defining the concepts under study and then identifying the indicators to measure these concepts. Construct validity can be challenging to assure in the case design because of its difficulties in developing a sufficiently operational set of measures and eliminating subjective judgments of a researcher's preconceived notions in data collection.

In order to assure construct validity in this thesis, three measures are taken. *First*, data is triangulated from multiple sources of evidence until the patterns from multiple data sources start to converge as specified in Section 3.4.2 regarding data analysis. *Second*, the researcher established a chain of evidence for all cases. The chain of evidence shows who, when, and where the evidence was obtained and secured. This helps to ensure the adequate citation of the relevant sources used to arrive at specific findings, as well as the adequate records of time, places, and circumstances consistent with the interview protocol and linked with the findings. *Third*, construct validity is assured by asking the informants to review transcripts and case reports and provide feedback, if any.

Notably, data triangulation is just one form of research triangulation. Easterby-Smith *et al.* (2009) discussed four forms of triangulation to ensure research quality, which includes: (1) Triangulation of theory: borrow a theory from one discipline to explain a phenomenon in another discipline. (2) Data triangulation: collect data from multiple sources or at various times to understand a phenomenon. (3) Investigator triangulation: use of different researchers to collect and analyse data. (4) Methodological triangulation: use a mixed-method to collect and analyse data. Because this thesis was conducted by one researcher and only one method was chosen, only triangulation of theory and data triangulation was deployed in this study.

3.5.2 Internal validity

Internal validity refers to the strength of the inferences from the research and largely depends on how rigorously the research is performed. Hence, strong internal validity is particularly important in the explanatory research to establish a trustworthy cause-and-effect relationship or infer a particular event from some earlier occurrence based on interviews, and documents when the event cannot be directly observed. The key concern of internal validity is whether the observed events can be attributed to the exposure and not to alternative causes or methodological errors. In the case study research, internal validity deals with the problem of inferences and is enhanced using the pattern matching technique when patterns across cases coincide. The comparison of these patterns is further facilitated by a structural analysis of the collected data in a tabular template that is built on the foundations of recognised principles of the circular economy and institutional theory literature.

3.5.3 External validity

External validity concerns the generalisation of the derived findings. While internal validity reflects how confident the researcher is with the findings of the study, external validity is associated with the transferability of the findings in other settings. External validity is guaranteed by three measures. First, the employment of multiple case design offers a higher chance for achieving analytical generation than a single case. Second, external validity is strived for in the form of setting initial RQs with how and why, which are consistent with the purpose of the case design. Third, external validity is strengthened by the selection of an appropriate theory – the extended institutional theory in this case – for laying the groundwork to address the external validity, and by following a theoretical replication logic in the case sampling. Unlike literal replication logic that selects cases with anticipated similar results, the theoretical replication logic carefully targets cases with anticipated contrasting results but for anticipated reasons. This also allows for building a coherent and diverse sample, along with describing the context and the cases. These measures need to be set in the case design stage.

3.5.4 Reliability

Reliability regards ensuring that the same findings and conclusions are reaped if a later researcher follows the same processes and conducts the exact same study again. Reliability criteria focus on assuring the rigour of the applied process and eliminating potential biases and errors.

The reliability of this study is sought by two measures. First, the research procedure is documented in a case study protocol to show a clear sampling criterion and structured research questions. Second, data is organised in a single folder that can be easily retrievable and facilitate later analysis. Third, reliability is attained via formalised coding to assure consistency in assigning the codes to the raw data.

3.6 Ethical consideration

Ethics refer to "*norms of conduct that distinguish between acceptable and unacceptable behaviours*" (Resnik 2015). In research, ethics infer the code of conduct that guide researchers regarding the rights of participants and those who might be affected by it (Saunders *et al.*, 2019). As each decision throughout the research process is argued to be an ethical choice, it is challenging to make a good choice that reconciles any possible conflicts of interest between the researchers and the research (Blaxter *et al.*, 2010). A typical example to illustrate the conflicts of interests is that when rushing to collect data for the research, the researchers may compromise the ethical practices that potentially lead to deceptive findings or infringe the rights of participants or potentially cause harm to the participants (Murphy and Dingwall, 2007; Oliver and Eales, 2008). All researchers are required to be aware of ethical practices and select an appropriate ethical approach, particularly when this study involves the gathering of information about main stakeholders' perceptions using semi-structured interviews. Ethical approval from the ethics committee at the University of Hull has been sought prior to the data collection stage. In the following, the choice of the philosophical foundation of research ethics in this thesis (3.6.1), as well as ethical practices in data collection (3.6.2) and analysis phases (3.6.3) will be discussed in-depth.

3.6.1 The philosophical foundation of research ethics

It is vital for the researcher to be mindful of his/her underlying philosophical foundations for research ethics because it offers a clear and unified account of what ethical obligations of the researcher are without referring directly to specific situations. Table 16 provides a summary of four classical theories for philosophical ethics, which include utilitarianism (outcome-based), deontology (duty-based), virtue (virtue-based) and contractarian (contract-based). This thesis follows the deontological approach in making ethical decisions throughout the research progress.

Table 16: Classical philosophical ethics

Classical philosophical ethics	Main idea
Utilitarian	which incentivises the actions of doing the most goods that benefit the majority of concerned parties. This is sometimes called consequentialism due to a reliance on the outcome of a decision.
Deontology (also known as Kantian ethics)	which underlines our obligations and duties to adhere to certain absolute or nearly absolute rules. This looks for transcendent principles that apply to all humans.
Virtue	which is based on the virtues of a person making a decision rather than a focus on rules that ought to be followed.
Contractarian	which employs the idea of contract and agreement among individuals in making ethical decisions. This is built on the premise of social contract theory.

Source: Created by author

Deontological ethics was founded by philosopher Immanuel Kant (1724-1804) who asserted that it is our duty to do the right things irrespective of the outcomes that might ensue. Deontological ethics is often referred to as Kantian ethics. Rationally doing the right thing is termed as the *categorical imperative* that acts as an unconditional principle for the actors to follow, even if it opposes actors' desires and emotions. In research, Kantian ethics suggests that the researcher should always follow rules and that acting outside the rules can never be justified (Saunders *et al.*, 2019). The unconditional duty to follow the rules and do the right things offers several advantages compared to other ethical approaches. *First*, the outcome-based utilitarianism ethic justifies actions by measuring the greatest good for the greatest number of people (Mill 1901). The problem is that different people may interpret "the greatest good" differently, which results in a variety of unanticipated actions in the same situation. In research, some of these actions may violate the codes of conduct at the University with a "maximum total utility" excuse. At worse, it could pose harm to the research objects including animals, humans or organisations the “good” ethical ground. Hence, I do not favour consequential ethics. Instead, I believe that all researchers have the duty and obligation to comply with the universal law of nature in Kantian ethics because humans cannot predict future consequences with a substantial degree of certainty, but can only guess about future outcomes that appalled him or her (Johnson and Cureton, 2021). *Second*, a virtue ethic embraces *the kind of a person that a researcher wants to be*, which is the key to ethical reasoning. It holds certain virtues such as compassion, integrity and honesty that transcend time and culture. Therefore, virtue ethics is not considered to be a hard-universalist theory that provides principles binding on all people regardless of time and location like deontology. From my perspective, the lack of a universal law makes virtue ethics highly contextual and vague or even imprecise to guide the researchers’ decision-making process. Again, despite its merit, I do not favour soft virtue ethics in research. *Third*, social contract theory though endorses obedience to the University’s regulations and codes of conduct but its obedience emanates from social pressures from external forces such as being punished by society, not from inside the researcher’s goodwill as specified in Kantian ethics. I argue that as a researcher, I should act ethically with willingness in order to safeguard the integrity and reliability of the knowledge creation process, safeguard public trust in science, and prevent misusing resources.

Deontological ethics with categorical imperative principle offer three implications to this study. Firstly, it generates consistency in the anticipated actions of everyone in a particular situation (Kant, 2017). The researcher should strictly comply with the University’s codes of conduct applicable to the PhD candidates, even if the outcome might not turn out to be favourable, such as a delay in PhD progress. Where the regulations and rules are inadequate or contested, it would be necessary for the researcher to reappraise and raise these points to the University in order to amend them, if required (Saunders *et al.*, 2019). Secondly, the categorical imperative requires that all participants should be treated equally with respect and dignity (Bonde & Firenze 2013). Under no circumstances, the researcher could deceive participants or hide the information to mislead them in order to obtain data. Lastly, the categorical imperative must not emanate from external influences and/or pressures but from the rational will of the researcher.

On the other hand, some shortcomings of Kantian ethics should be discerned. Firstly, Kantian ethics can appear to be rigid and impersonal in some instances so harm might be inflicted (Bonde & Firenze 2013). Secondly, if a situation involves more than one conflicting duty, Kantian ethics does not offer the mechanism to cope with an ethical dilemma (Bonde & Firenze 2013). In this context, I should seek advice from my supervisor or email the University’s Research Committee and Ethics Committee. Again, inspired by Kantian ethics, throughout my entire PhD process, I am aware of my duty to ensure that I continuously act with ethical vigilance in conformity with the codes of conduct at the University of Hull.

3.6.2 Ethical issues in the data collection

Each type of data collection techniques such as interviews, questionnaires, surveys, or observations can arise different ethical issues (Saunders *et al.*, 2019). As the study uses interviews, observations and secondary data, the following measures concerning ethical considerations in data collection had been followed (Murphy and Dingwall, 2007; Oliver and Eales, 2008):

i. Obtain the written informed consent from participants in alignment with the University ethics guidelines and code of conduct for the researchers. The full informed consent forms were submitted to and approved by the ethics committee at the University of Hull before carrying out the research.
ii. Respondents were invited to suggest the date and time at their convenience for the interviews to be carried out.
iii. The interview guide was sent before conducting the interviews, permission for recording was requested, and participants were given the rights to turn it off at any time.
iv. Interviews were conducted in a professional manner without causing harm or discomfort to participants physiologically, emotionally, socially and economically. Participants were given the right to withdraw consent at any point and to refuse to respond to any questions when they perceived doubts about the research process or the use of the information. Multiple contact information concerning the study was provided to the participants, including contacts of the researcher and the research supervisors. In addition, any kind of discrimination against genders, races, social classes or ages during the process needs to be eliminated.
v. Anonymity and confidentiality of participants and their companies were ensured by not mentioning names or information which has the potential to impact their confidentiality.
vi. The interview transcripts were sent to the respondents to validate the data and seek additional feedback or amendments if any.

It is noted that informed consent implies that "*a person knowingly, voluntarily and intelligently, and in a clear and manifest way, gives his consent*" (Armiger, 1977, p. 330). This effectively means that the researcher needs to disclose sufficient information about the research to the potential participants, ensure that participants can comprehend the provided information and be able to make their own decisions about whether they wish to participate (Burns & Grove 2005). This is called the principle of autonomy which is achieved through a self-determination process (Beauchamp & Childress 2001). As such, the consent forms were sent to participants accompanied by an information sheet (Appendix 2) containing key information about the research. The consent form also provides the planned interview duration, potential risks and rewards linked to the participants, the level of confidentiality and anonymity, as well as the rights of participants to raise any query or leave the research at any point. No coercive means are done on the participants. Furthermore, the researcher is aware of different levels of consent, including lack of consent, inferred consent, and full consent (Saunders *et al.*, 2019). It is important to obtain full consent because both inferred consent and lack of consent are unethical behaviours that should be avoided at any cost in order not to cause harm to participants like the Tuskegee study about syphilis (Saunders *et al.*, 2019). These ethical considerations are also aligned with Kantian ethics which discredit the researchers who make use of another person as merely a means to the end.

3.6.3 Ethical issues in data analysis and thesis writing

Data analysis and thesis writing stage must be conducted to ensure research objectivity and integrity (Saunders *et al.*, 2019). Research objectivity is met by presenting the data objectively and avoiding distorting outcomes. Research integrity is maintained by preventing any misconduct behaviours that could impact the trustworthiness of this thesis, which might consist of fabrication, falsification, and misrepresentation of the data.

Meanwhile, the researcher is mindful of the ethical challenges coupled with the maintenance of confidentiality and anonymity at this stage. Some measures were put forward to ensure confidentiality and anonymity. The responses of participants are not disclosed to anyone without participants' consent. The names of participants, either companies or individuals or any connecting information like ages or job descriptions are disguised to prevent exposing their identity. Pseudonyms are assigned to both individuals and companies while only the data that supports the findings are disclosed. Passwords are set to all data including audio, video and email records. Participants reserve the right to access the data relating to them and have the right to request to delete the data. Furthermore, data collection, analyses and interpretations were presented to the supervisors to ensure no invasion of privacy and deception. Based on the feedback of supervisors, case companies were further disguised.

3.7 Chapter summary

The chapter reveals how and why the interpretivism paradigm is chosen to guide this abductive multiple case research design. The rationales for research approach, research strategy as well as data collection and analysis to obtain gain an in-depth understanding of practices, drivers and barriers to circular food by-product management are thoroughly discussed in the wider business research context. Finally, measures taken to assure four dimensions of research quality and ethical considerations that are pertinent to this research design are elaborated in detail.

Chapter 4 Within-case analysis

In this chapter, individual cases and their context will be dissected and discussed in detail. This in-depth data case-by-case analysis offers few advantages (Eisenhardt, 1989). First, it facilitates the organisation and presentation of the huge amount of data collected in each case, which is a special feature in the case research design. Second, it allows the researcher and the readers to be familiarised with each case as an independent entity and thereby exposing the unique patterns before patterns across cases are generalised in the cross-case analysis. The following will present the details of each case concerning the company background, the overview of prevailing treatments in the incumbent firms, different aspects of the innovation efforts including purchasing, technology and end-products with the associated markets, and the perceived drivers that lead them to engage in the circular economy innovations, and the barriers experienced on its journey. In other words, the key findings from the individual cases with respect to the research questions will be analysed and presented here. This structure of analysis contributes to enhancing the transparency and traceability of the outcomes while preserving the peculiar trait of each case.

4.1 Case A1 – Valorisation of garlic by-products

Case A1 is an existing vegetable processing firm with a weekly capacity of around 2,000 tonnes of root vegetables such as lettuce, cabbage, etc. Case A1 has operated an AD plant next to its factory to process its processing residues but encountered an issue with garlic by-product treatment. Garlic by-products are the residues from the puree production process where the whole garlic pulps are heated to dry the outer skins and then pressed to crack garlic cloves out before being crushed for garlic puree production. Garlic wastes from the puree production process contain garlic stalks, straws, and skins with some residual pulp. Hence, garlic wastes contain quite a lot of fibrous material left that can be utilised. In an endeavour to find a better valorisation route to extract more valuable products from garlic residues, case A1 engaged in testing two technological options: distillation and supercritical fluid extraction (SFE) for garlic oil extraction.

4.1.1 Overarching picture of the current garlic by-product management in the UK

The garlic processing sector generates a massive volume of solid wastes that account for 25-30% of material input (Kallel and Ellouz Chaabouni, 2017). Two main types of garlic processing wastes are stalks and skins (also known as husk or peels). Garlic skins contain ash (5.6-16.65%), fat (0.86-4.2%), protein (8.43-13.1%), lignin (8.31%), and fibre (58.4-62.23%). Garlic stalk is made up of ash (10 ± 0.30%), fat (3.2 ± 0.12%), protein (4.38 ± 0.21%), lignin (6.32 ± 0.36) and fibre (24.1 ± 1.70%). The composition of garlic by-products presents industrial applications such as feed alimentation, soil amendment, bioenergy, and bio-adsorbents for wastewater treatment (Kallel and Ellouz Chaabouni, 2017).

According to two interviewees, case A1 previously used garlic by-products as a soil amendment or as feedstocks for its AD plant. First, garlic by-products once decomposed help to improve soil quality by changing nutrient dynamics and soil enzyme activity, which in turn boost total organic carbon and organic matter in the soil. A1-1 revealed: "*The waste material typically was sprayed on fields so that all the garlic oil is left in that was just allowed to evaporate into the atmosphere. And then the remainder was ploughed back into the field to add organic matter to the field… farmers use this waste as organic matter to improve soil rather than fertilisers*". However, case A1 expressed the difficulties associated with the handling process in terms of carrying garlic wastes to the fields and laying them out on the fields, which is not only complicated but also expensive. Second, as a feedstock for AD, garlic by-products along with other vegetable by-products are sent to the nearby AD plant to produce biogas and digestate. Nevertheless, A1 expressed concerns about the potential technical issues associated with the use of garlic by-products due to sulphur-containing compounds in garlic straw. A1-1 explained the mechanism: "*Sulphur in anaerobic digestion can sometimes inhibit the performance of an anaerobic digester. We fear that there may have been a technical barrier to using it in the anaerobic digestion later on*." Of note, the interviewee (A1-1) clarified why smells eradicate animal feed production from possible treatment routes for garlic residues: "*In some cases, it's possible to feed that kind of vegetable wastes to five livestock. In this case, that wasn't possible because the waste is quite aromatic. And farmers don't like that flavour tainting the meat of the animals that eat it. So it couldn't be used as feed*".

As for the innovation landscape in the garlic by-product treatment, case A1 does not know any practical business cases that involved valorising garlic by-products to produce higher added value materials/products in the UK context. They further indicated that potential technologies for recovering high value-added compounds from garlic residues such as supercritical fluid extraction are available, but the scale-up challenges and a lack of a clear market mechanism for the output products hinder the success and widespread of innovation efforts.

4.1.2 Circular economy practices

In an effort of delivering more value from garlic by-products, case A1 has been involved in testing two following technologies: steam distillation and SFE (illustrated in Figure 7).

In steam distillation, one of the common ways to extract aromatic oils from the plant, hot steams are forced through a mixture of garlic by-products to release the volatile components from these materials. Then, the volatile comments are condensed until receiving an oil and water layering in the collection vessel. After discarding the water, garlic oil is retrieved. However, the process involves the use of high temperatures (100 degrees), which impair the quality of oils recovered. A1-2 mentioned: "*The problem with that process is that you're obviously heating the garlic up. And that causes a certain amount of damage to the quality of the product. So while what comes out of it does smell and taste like garlic, you can't claim that it's a natural garlic flavour profile, because the chemicals in it aren't exactly the same as you would find in natural garlic if it were extracted."* Though this technology is highly suitable to the capability of the factory, case A1 did not recover the product at the desirable quality, which led them to test a second extraction technique using SFE.

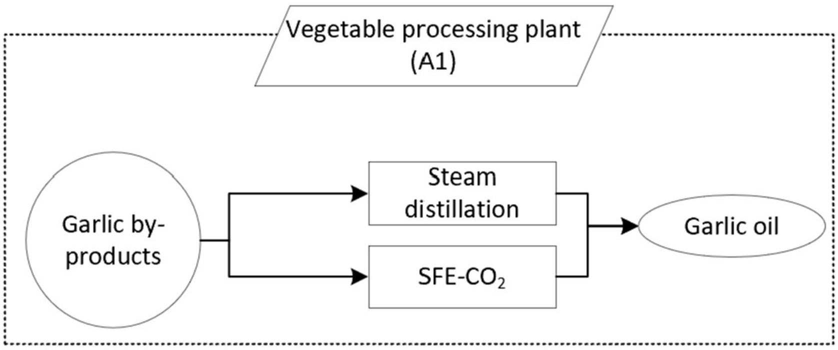


Figure 7: Circular practices employed in A1

Source: Created by author

SFE–CO_2 uses high pressure to liquefy carbon dioxide, then this liquid carbon dioxide becomes a solvent that passes through garlic by-products. Garlic oil dissolves in the liquid carbon dioxide. After releasing the pressure the carbon dioxide evaporates and what's left behind is the garlic oil. Due to the lower temperature (only about 30 degrees), SFE is more effective in the sense of protecting the quality of garlic oil. At the lab-scale test, case A1 was able to retain high purity garlic oil with a strong aroma. However, the SFE is more complicated than 'a big kettle' steam distillation as it involves the handling of high-pressure carbon dioxide. Additionally, garlic by-products contain a lot of water which interferes with the extraction process, so case A1 needs to add an additive to mop up the water. This escalated the cost and complexity of the technology. Coupled with not being able to find a partner that provides an SFE-CO_2 unit that can process a volume of 1000 tons of garlic by-product per year on its site, A1 had to give up the project in the end.

Although the project has not reaped commercial success, its innovation efforts provide useful lessons learnt and fit in the research objectives as well as contribute to answering the research questions.

4.1.3 Perceived drivers

Case A1 established that the key driver for its laboratory project came directly from receiving a government grant in a collaborative project with some external researchers from renowned universities in the UK. A1-2 indicated: "*Because there was external available to pay for the project, it seemed like a good time to test it.*" A1-2 further mentioned the source of funding that comes from the Biotechnology and Biological Sciences Research Council (BBSRC) channelled through two networks called Network in Industrial Biology and Biotechnology (NIBV) and FoodWasteNet.

Besides this clear driver, A1 also mentioned two additional stimulations for their innovation efforts. First, A1 expected a potential economic benefit from better recycling its own waste stream. This benefit derives from two sources including an additional revenue stream from the end products and cost-saving from not treating garlic wastes in the AD plant. As well-explained by A1-3: "*It was the financial combination of the two things as a financial driver. Firstly, you might make some money directly out of this waste stream. And secondly, you might save some money by not inhibiting the AD plant when that was built. So those two together made for a good financial case, which was probably the one that interesting, most people are the most*." Second, this valorisation project is asserted by both interviewees for its fit in case A1's broad corporate social responsibility (CSR) at the time of engagement thanks to better management of its own waste stream.

4.1.4 Perceived barriers

Case A1 has offered five barriers that prevent the garlic by-products valorisations in the UK:

First, there is psychological fear. Case A1 is a vegetable processor, not a waste recycler so it sees garlic by-product valorisation effort as a distraction from its main business line. A1-1 revealed: "*I guess there is a psychological fear, the fear of unknown. It's quite a conservative business. So there wasn't a lack of it wasn't there regularly interest in pursuing innovation in that particular company. So there was a there was an organisational and attitudinal barrier there, I suppose".* Hence, it thinks that vegetable processors are reserved in the decision to engage in any biotechnology investment efforts. Now, the obvious one is that we are a food company. If the market ended up being in another category entirely another sector, we would have needed either a partner to reach the market, or simply a customer of the product we sold, who was then active within that market.

Second, there is a lack of clear market mechanisms for the end products. The novel by-products-derived oils have not been sold in the market yet so the market value of this product is unclear. A1-2 acknowledged: "*There was no end game in sight. We didn't know which came first. So they* *were it was a chicken or an egg in the way… because we didn't know the quality of our product we could produce. We have not been able to say very clearly if there is a market that we could potentially address*".

Third, financial risk is a barrier. The unclear market value of the end-product directly links to the high risk of technological investment. A1-1 explained: "*there's also the commercial concern that if we're going to spend 200,000 pounds on extracting garlic oil, what else could we spend 200,000 pounds on that might give us a better, more manageable and more understood return*."

Fourth is the scale-up challenge. In the case of SFE-CO2, output products obtained in the lab are satisfactory. However, the project was abandoned because case A1 was unable to find a supplier that can provide the technologies at the scale of handling 1000 kg by-products per year. A1-2 underlined this issue: "*There is a genuine technological barrier… We couldn't find a partner that can provide us with a scale-up facility that would take us to a large enough scale to enable us to assess how it would at a volume, maybe 1000 tons a year of garlic. By the time we gave up on the process, we'd found the partner who was looking to develop containerized to supercritical fluid extraction unit, which could be left on the site, but we did not be able to secure funding to continue"*.

Fifth rests with resource incompatibility as two prohibitions preventing them from pursuing this further. Case A1 also suffers from resource compatibility as the novel extraction technique would require case A1 to be equipped with different skills, equipment, and experience that might be challenging to sit side by side with the existing business. A1-1 recalled: "*At that particular company was much more about acquiring or partnering with those who have existing technology, because, as I've already said, that the technology involved to peel and slice vegetables is not very high. It's something that we can do in our own kitchens with a knife and a chopping board. It's just an industrial-scale version of that. So it's it was not a very complex set of operations, therefore, to introduce complex operations, would be even running the ad plant is quite complex for that site. So running a high-tech extraction process, with maybe event to company complicated, so we would have looked for a partner*."

4.1.5 Case summary

In summary, case A1 was involved in finding a better use of garlic by-products by distillation and SCF to extract garlic oils. When garlic by-products are commonly used as oil additives or feedstocks for biogas production in AD, case A1's innovation efforts contribute to retaining higher value from this waste stream.

Its motivation stems mainly from (1) the availability of government funds and partly from (2) the potential economic benefits as well as (3) the enhancement of CSR. However, both innovation efforts using distillation and SCF-CO_2 have been discarded due to a combination of five factors: (1) psychological fear in the engagement in upcycling innovation (2) lack of a market mechanism, (3) financial risks, (4) technology scale-up challenge, (5) capability incompatibility.

4.2 Case A2 – Valorisation of fruit pomaces

Established in 2014, case A2 specialised in the valorisation of processing fruit pomace to export into the foreign markets (60% to EU and 40% to China). Founded by a farming family business with hundred years of experience in arable, dairy, cattle, and sheep in the UK, case A2 has accumulated vast knowledge in drying arable crops. It now aims at the valorisation of fruit processing pomace to reintroduce its back to the FSC and contribute to keeping this valuable resource stream out of the waste bin by leveraging its capability to process these materials in a fast and efficient manner. Resource optimisation is the cornerstone in A2's development.

A2 has engaged in laboratory-scale experiments to extract fibres and seed oils from by-products of the blackcurrant and apple processing industries using enzyme hydrolysis. However, its commercial operations focus on drying these pomaces at a large scale using six industrial drying machines to produce natural fibres for confectionary manufacturers and dried seeds that are exported for oil extractions in other countries. An additional revenue stream in case A2 comes from renting out drying equipment to other firms to process mushroom stalks – a by-product from the mushroom industry. These companies dry and process mushroom stalks to produce mushroom powder used for vitamin D supplementation.

4.2.1 Overarching picture of the current fruit pomace management in the UK

The fruit processing industry for juice, jams, purees, cider or wine etc., generates high amounts of waste materials in the forms of pomace, peels, and seeds.

In the case of blackcurrant, its by-products, which represent 24 ± 4% of fresh fruits, mainly consist of seeds and skins (Sandell *et al.*, 2009). Seeds have a high concentration of flavonoids and phenolic acids, and high oil content (27 to 33%) which is a good source of essential fatty acids, tocopherols, and phytosterols. Hence, seeds are often used for extracting oil and phenolic antioxidants (Bakowska-Barczak *et al.*, 2009; Basegmez *et al.*, 2017). Skins, one of the richest sources of anthocyanins (natural pigments) can offer alternatives to synthetic colourants and bioactive ingredients for food and healthcare products (Yang *et al.*, 2019).

As for apples, its by-products (pomace), which make up 25–30% of the total apple wastes, consist mainly of skin and flesh (95%), with a small content of seeds (2%–4%) and stems (1%)

(Lyu *et al.*, 2020). Apple pomace is a rich source of carbohydrates, pectin, crude fibre, proteins, vitamins, minerals, and phenolic compounds (Perussello *et al.*, 2017). Apple is normally used as livestock feed despite its low protein content and metabolizable energy content. Pomace is a promising raw material for the production of bioactive compounds and high-value-added products like organic acids, enzymes, biofuels, pectin and phenolic, or dietary fibres (Dhillon *et al.*, 2013; Mirabella *et al.*, 2014; Perussello *et al.*, 2017).

In general, literature widely acknowledges the potential of the pomace of blackcurrant and apple for the biotechnology industry thanks to its chemical compositions to generate products and materials in a range of sectors: nutraceutical, foods and feed nutrition, cosmetics, and polymer. In addition, multiple novel extraction techniques to recover these compounds are discussed, including enzymes, electric field, ultrasound, microwave heating, pressurized liquid, and super/subcritical fluid (Basegmez *et al.*, 2017; Perussello *et al.*, 2017).

Despite its great potential, interviewees emphasise that both apple pomaces and blackcurrant pomaces are often treated by the least favourable methods at the bottom of the waste hierarchy, mainly AD or animal feed production. The Director (A2-1) asserted: "*If it's got any energy or protein in it, then AD will buy anything with. Even just water with a little bit of waste in it, it becomes useful to an anaerobic digester. Although this might be more expensive, anything with food having protein and carbohydrates that can generate a gas yield, they're interested*". When utilised for livestock feeds, case A2 revealed the disadvantages of this pomace in terms of low protein content and less metabolizable energy content. Case A2 expressed its preference to recover valuable materials from these pomaces back to the human chain rather than the low added-value AD treatment.

4.2.2 Circular economy practices

This section will dissect A2's circular economy adoptions in three areas: procurement, operations and technology, and products and markets (Figure 8).

For procurement, case A2 acquires large quantities of blackcurrant and apple pomaces from large juice pressing and cider manufacturers in the UK. Pomaces are collected by trucks on the daily basis to maintain the quality of raw materials.

For operations and technology, these pomaces, once arrive, are cleaned and dried in specialised dryers and cleaners before being micronized to create a fine flour that is suitable for being ingredients of confectionery, chocolate and bakery products. In this process, seeds are removed. As drying requires the extensive use of heat, the processing is designed to capture the residual heat and export it to the district heating system to reduce waste heat as far as possible. The process is accredited with Safe and Local Supplier Approval (SALSA) standards. Although the scope of case A2’s operation at a commercial scale is only limited to the drying operations of fruit pomaces at the time of the interviews, drying is a first and crucial step in the upcycling chain. This is because the extraction from the dried mass is more effective than from wet mass as the phytochemical degradation process occurs rapidly in a high moisturised environment. In addition, the choice of drying method and operation parameters determine the physio-chemical properties of the end-products such as seed oil in this case. A2-1 also underlined: “*Well, the main thing is to stabilise and maintain stabilise a wet seasonal waste. All these wastes are wet, and they will deteriorate if we don't dry it*”.

Besides drying operations, case A2 has been collaborating with the leading UK Universities and allowing their PhD students to conduct some experiments using advanced technology like different enzymatic extractions on different types of products, including pomaces and brewers’ spent grains, to evaluate the quality of end products in terms of antioxidant activity, the content of polyphenols, total, soluble and insoluble dietary fibre. In this regard, case A2 showed its interest to engage in seed oil extractions by itself to shorten the supply chain. C2-2 specified: “*Normally we sell just seeds, but now we're looking at a little bit closer to the customers so we're not just supplying the blackcurrant pomaces overseas, we're now looking at crushing the seed to get the oil with rich GLA and the Omega-6 … We know there is another firm that markets directly to the customer. So, we're going to go vertically integrated there*”.

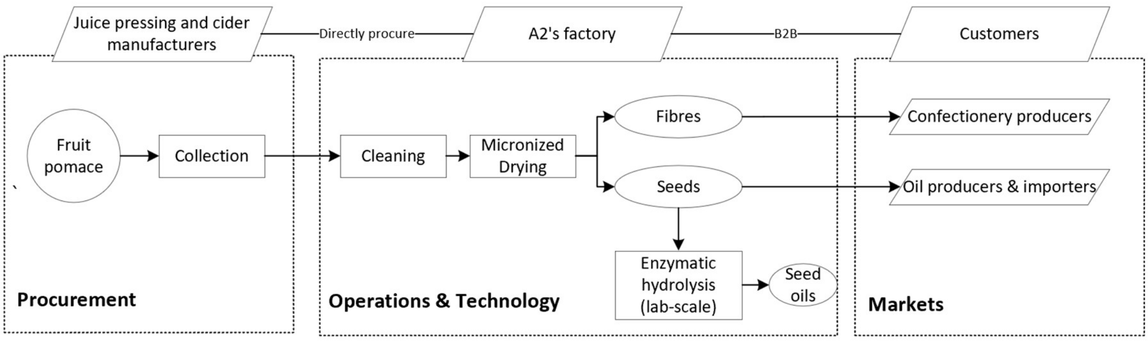


Figure 8: Circular practices employed in A2

Source: Created by author

For end products and markets, case A2 offers two finished products at the moment: food ingredients with high added value from food by-products and dried seeds. First, pomace-derived ingredients, which are a rich source of polyphenols and fibre, are sold to the UK confectionery companies to be introduced into cereal products. The pomace flour demonstrates low-sugar and high-fibre levels, which contributes to tackling sugar issues in the UK public health. Second, dried seeds are separated and sold to the importers in mainland Europe and China. In the importing countries, the seeds are crushed for essential oils while the skins are used to parenthesise natural food colourings. Interview A2-1 added: "*We don't actually do the extraction of the anthocyanins we just do the drying and the sieving, just basic processing*. *But we export all over the world so that's natural food colourings, Omega-3 omega-6 oil, sort of essential oil*".

4.2.3 Perceived drivers

The involvement of A2 in the circular food by-product recycling chiefly arose from two factors:

First, low capital investment drove A2 to engage in this innovation. This driver emanated from A2's ability to acquire and reconfigure the dryers from other industries at a cheap price. A2-1 stated: "*We're glad to have six altogether. Three of them are from driving human sewage wastewater, the industry they were taken from. And we've transferred them into human foods by getting a very clean… So we bought scrap equipment really, and we* reconfigured *to make it work again.*" This has given them a competitive advantage compared to the competitors with new machinery investment. A2-1 supplemented: "*Each drying machine costs us around 25,000 pounds, a new machine will be one and a half million… If you start with one and a half million pounds of overhead for a new machine, and then a building put in let's say 200,000 borrowed money at 7% interest. You've straight away got a really expensive piece of equipment…. And we haven't. We paid 10,000 pounds a year to rent the building and the equipment was 30,000 pounds".* Lowering initial capital investment also enables them to play around with the new 'waste' market that they switch into as cited by A2-2: "W*e can afford to make a few mistakes and we can be on margin is coming from cheap equipment."*

Second, case A2's engagement can trace back to its experiences in drying and farming businesses. In addition, the Director, also the founder, has a strong background in engineering and agricultural technology and is responsible for designing process flows for the food drying factory. A2-1 acknowledged: "*My family's been farming on this farm since I think 460 years. We've been farming in this area for 500 years, including the next-door farm … We were partly doing it already because we were drying a lot of food waste, and that was drying maize. So that was seasonal and initially, the big motivation is to try and spread out the workload throughout the year*". The overarching message in the interview indicated that the involvement in the food by-product areas has been the real challenge, and the only propellor for Case A2 to continue moving forwards comes from the dedication and hard work of the owners. The Director (A2-1) recalled: "*We reply to hundreds and hundreds of emails every day …, I don't want to belittle it. I've got to spend many hours, dealing with inquiries and possible connections, and supplies of waste. So I've got to think of sending 35,000 emails in the last three years. It's a lot of emails and many hours,* *every weekend evening until midnight. It isn't by accident we have we do have to work quite hard"*.

In addition to these two drivers, case A2 was partly stimulated by the government aid in form of networking opportunities. Specifically, the business grew strong thanks to a collaboration opportunity with a big confectionery corporation in the UK, funded by Innovate UK, in response to Public Health England's drive for reduced sugars by 2020. Case A2 also received other support in the forms of staff training, strategy and policy development from a Sustainable Hub program funded by the European Regional Development Fund to support businesses in low carbon services and sustainable technologies. Although the support is cited to be small at a size of a few thousand pounds, it is proven to be useful to get them closer to the potential customers or at least to people of the same interests in food waste management areas. A2-2 commented: "*Government support was a little one, but… sometimes it's the little ones that get your foot in the door, then you go to some meetings and then I involved by going to a committee. I sat on a committee that was talking about food waste, and then you have an idea, we hear something or somebody who introduces you to somebody else. And that's how we're getting these contacts with [a global confectionery brand] for apple pomace, with mushrooms."* The Sale Manager also explained that the majority of their connections come from very small leads in the beginning, but this worth of mouth has been effective to make them visible at the exact place and time that their customers demand: "*When people say how do you how do you find these customers: Well, some of them are finding us some pointers because we're there for the website."* (A2-2).

4.2.4 Perceived barriers

Case A2 has provided the following barriers that prevent the eggshell valorisations in the UK:

First, the seasonality of pomace causes sourcing risks, that disrupt the operation of case A2. As expounded by A2-1: "*We have been going on for 10 years, but it's very seasonal … blackcurrant has a very short time window in July and August only so our dryers just busy in few months, and it's doing nothing for the rest of the year…. We can't absorb any more costs because the biggest cost goes to labour for the rest of the year… That is very expensive, you know that's £100,000* cost*".* To overcome the seasonality issues, case A2 is looking at two possibilities widening its product portfolio to include other crops (such as brewery's grains or yeasts) or importing blackcurrant from other countries, such as Chile, South Africa, and Portugal. A2-2 stated: "*We're trying to develop other crops at either other times of the year or four year-round impossible… We're looking at yeast, grains, mushrooms. And we did some experiments but not a real project*". In addition, case A2 also rent out the dryers to process mushroom stocks.

Second, sourcing contract in the pomace business is typically short, which causes a massive risk to the business. A2-2 indicated this risk: "*Because it's very risky having just one year and two-year contracts is terrible…. I think developing another industry like yeast or brewers' grains, which could roll from year to year, will be very good news*".

Third, there is a lack of a clear market mechanism, so case A2 keeps trying and testing out a few crops along the way. Case A2 was set up by leveraging its 'cheap' machinery advantage, then trying out different by-product materials including pomaces, brewery grains and yeast to get into different markets. This is not a conventional way of setting up the business as expressed by A2-1: "*We thought we can afford to make a few mistakes coming from cheap equipment… But what you should really do is that you should pretend you've got expensive equipment to absorb the massive risk in this business.*"

4.2.5 Case summary

In summary, case A2's operations mainly involve drying pomaces for further processing by oil extraction firms and converting pomaces to be natural colourants for the food processing sector. When pomaces are commonly fed in AD plants or low-value livestock production in the UK, case A2 has added much higher value to this waste stream. Although case A2 only engages in the initial step of the by-product value chains (pre-treatment and drying stages), it has engaged in R&D projects using enzyme hydrolysis to produce oils and colourants locally and thereby shorten its value chain that is currently exported. Notably, A2 does not have its own laboratory but relies on external resources via collaboration with renowned universities.

Case A2's involvement was primarily derived from (1) low capital investment and (2) internal capability thanks to experiences with drying and arable farming business and partly facilitated by (3) regulative aids via networking. Case A2 experienced three barriers in its operations: (1) sourcing risk due to seasonality, (2) short sourcing contract, (3) lack of a market mechanism for output products.

4.3 Case A3 – Valorisation of eggshells

The company, a small company located in the Midlands UK, was set up to valorise and commercialise the by-products from the egg processing companies. At the time of the research, the case has successfully produced a number of valuable materials from eggshells at the laboratory scale. The pilot factory is expected to initiate in 2023, and once completed, A3 can be able to demonstrate the techno-economic feasibility of this novel production process of high-quality materials that can be used for a range of industries, including foods, healthcare, and pharmaceutical. "*We are able to produce material, use the samples and potentially sell to people.*

And hopefully, it would be in a position where we could break ground on a commercial facility a year later - So the first quarter 2023 with production being a sensible level, a year later." (A3-1) Case A3 noted that the success of their current technology enables them to identify a genuine market that got value, which is the big problem with waste recycling firms. The factory once put in operation will meet the stringent specifications of the USP, BP, EP and fulfil the requirements of ICH Q3D, for consistently low heavy metals.

4.3.1 Overarching picture of the current eggshell management in the UK

The global food processing industry generates huge amounts of solid residues in the form of shell wastes each year (Wei *et al.*, 2009; Oliveira *et al.*, 2013). In the UK alone, the interviewee highlighted that the annual eggshell figure reaches 15,000 tons. The shell wastes that comprise two components: eggshells (94%) and membranes (6%) represent about 11% of the total weight of hen egg (Quina *et al.*, 2017). *First*, the eggshell is made of 94% calcium carbonate, 1% magnesium carbonate, 45 organic matter and 1% calcium phosphate (Stadelman, 2000). Calcium carbonate obtained from eggshells can be used as a human dietary supplement or as the base material for medical treatment such as bone and dental implants. It also has a wide range of industrial applications (e.g. as an agent in removing heavy metals from water and soil, as a substitute for minerals in paper treatment, as a catalyst in biodiesel production and as fertilisers in agriculture). *Second*, the membrane is made up of 70% proteins, 11% polysaccharides, and other compounds such as lipids and carbohydrates (Nys and Gautron, 2007). While protein in the membrane contains 10% of collagen (type I, V and X) and 70–75% of glycoproteins, polysaccharides contain chondroitin sulphate, hyaluronic acid and uronic acids (Nys and Gautron, 2007). Thanks to the rich bioactive compounds in its composite, the membrane has the potential to produce the hydrolysed or concentrated proteins and collagen to be used in the food and nutraceutical sectors (Oliveira *et al.*, 2013). Hence, there is a growing interest in studying the potential uses of eggshells (Vandeginste, 2021). Quina *et al.* (2017) synthesised and classified potential uses of both shells and membranes into two groups: raw materials and operating supply. Raw materials include food additives, soil amendment, purified calcium carbonate, cosmetics, and biomaterial composite. The operating supply group consists of catalysts for biodiesel production, lactose isomerisation, dimethyl-carbonate synthesis and sorbent for soil heavy metal immobilisation, water and wastewater pollutant removal, and CO2 capture. In UK law, eggshells are classified as animal by-products with low risk and can be processed by incineration, thermal processing, pet food production, composting, and biogas production (Quina *et al.*, 2017).

However, according to the interviewees in case A3, the huge volume of nutrient-rich and low-cost eggshell materials is commonly treated as *wastes* and disposed of by either spreading to land as fertilisers (soil addictive) or at landfilling sites without resources recovery. Although landfilling indicates a resource leakage and should be eliminated according to the circular economy, this remains popular in the UK context. Unlike landfilling, land-spreading enables naturally occurring bacteria and fungi to decompose organic matters in eggshells, thereby converting them into useful soil additives. Land spreading facilitates the recovery of nutrients from eggshells back to the soil and contributes to closing the loop in the FSC. To spread eggshells on farmland as a fertiliser, firms need to comply with the UK's regulations to avoid the spread of disease and odour emissions. However, interviewees cited two main problems associated with land spreading. First, the conversion of eggshells into useful soil addictive only works for certain crops but not for others. Second, its effectiveness depends on weather conditions. *"If the weather was that cold, the eggshells don't break down. They're getting to the point where they, they can't do it anymore."*

4.3.2 Circular economy practices

Against this backdrop, case A3 has engaged in R&D to develop eco-friendly solutions to recover high value from eggshells. Their circular engagement is analysed in three parts: procurement, technology and operations, and end-products and market (as illustrated in Figure 9)

For procurement, Case A3 has initiated the discussions with the three largest UK eggshell processors: "*The UK generates roughly 15,000 tonnes of waste eggshells produced every year. And there are probably three or four companies producing over 50% of that. We've had discussions with, with these three largest companies*" (A3-1). These processors are willing to give case A3 the eggshells for free because these eggshells are normally treated as wastes, which incurs an expensive disposal cost. To secure a continuous supply, case A3 is negotiating to secure long-term contracts, typically five to ten years, with these suppliers. Furthermore, to reduce the sourcing risk, A3 follows a multi-sourcing strategy in which only 50-70% of the input materials come from these main suppliers while the remaining comes from other sectors, e.g., hospitality. At each processor site, a container will be put there to capture and stabilise the eggshell materials. The container, once full of stabilised eggshells, will be transported to the central plant near Chesterfield by truck.

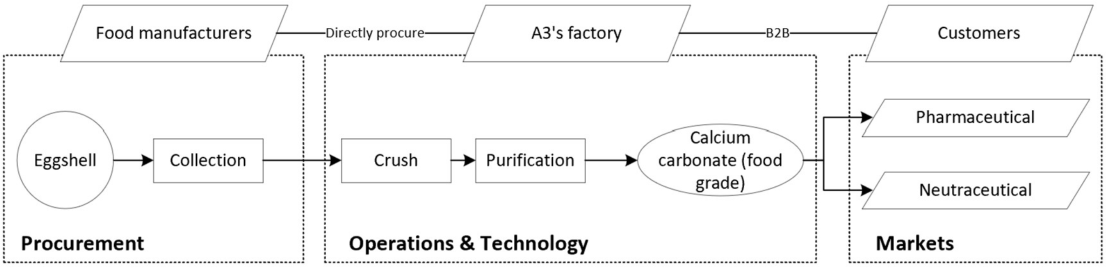


Figure 9: Circular practices employed in A3

Source: Created by author

For operations and technology, eggshells once arriving at the factory will be crushed and purified to be converted into food and pharma-safe pure calcium carbonate. Techno-economic analysis has been carried out to evaluate the economic feasibility of the project and deliver favourable outcomes. Finished products have passed the E170, BP/USP specifications for pure calcium carbonate required in the food and pharmaceutical industry. The entire production process also fulfils the requirements of ICH Q3D for consistently low heavy metals. The factory will have an expected capacity is of 67,000 tons of output materials each year. In its strategic development, case A3 aims to become the leading supplier of high purity food and pharmaceutical grade calcium carbonate.

For products and markets, A3 currently aims at the production of premium-quality calcium carbonate that can be extensively used in the food, feed, pharmaceutical, construction, manufacturing and a host of other major industries. Eggshell-derived calcium carbonate can replace the mined materials that show the risk of contamination and depend on the importing chain from China. "*There isn't the risk of having heavy metal contamination or a large carbon footprint as the mined materials. A lot of the mined material is being shipped from Asia and has a large carbon footprint. The risk of contamination puts costs into the system, and puts risk on the ultimate end products. Technically, we've got material that is as good as the best on the market…*" (A3-2). As calcium carbonates are widely used in the pharmaceutical market for drugs like antacids or calcium treatments, there is a toxicity concern for calcium carbonates made of mined carbonates that could potentially build up heavy metal contaminants and cause toxicity. Hence, materials from eggshells can eliminate this risk.

With this product line, Case A3 plans to enter pharmaceutical and nutraceutical markets. As a start-up, the company has actively promoted its products via different marketing tools. A3 expressed its efforts in getting its product to these markets: "*it's something we need to just sort of start putting out a background level of awareness to people. So if someone picks up the phone or sends an email, people know who we are, what we're actually offering…. Basically, I've got* *staffs who will go out and knock doors and develop the relationships…*"(A3-3). In the nutraceutical outlet, case A3 has developed a good understanding of the market mechanism and quality expectations. A3-2 specified: "*We've talked to the largest supplements manufacturer in the UK. if we've got a product that meets a specification, and we can do the price that they want, they will actually buy so we want to pick their brains.*" Right now, they have already received some positive signals from large supplement corporations in the market. The profit margin of this market is viewed as low compared to the pharmaceutical market, but the market entry of the pharmaceutical sector is very high. As highlighted by A3-2: "*Unfortunately, the white powder [calcium carbonates] comes in many forms. We need to understand what size distribution they want, do they need it coated, are they using it in tablets or capsules?"* Hence, A3 aims firstly at the supplement market and gradually expands to the pharmaceutical market in the long term. The founder justified: "*Supplements market is going to be our first port of call. It won't be particularly profitable, but the pharmaceutical market is going to be a long haul because they're very resistant and conservative. The regulations are ridiculous, but the rewards are quite high"* (A3-1).

4.3.3 Perceived drivers

The establishment of A3 was primarily attributed to an authentic commitment to upcycling eggshells and government funds.

First, case A3 committed to finding a better valorisation route for the high-quality eggshells. As mentioned above, in the context of 15,000 tons of eggshells discharged from manufacturing plants in the UK each year, interviewees see a significant waste of potential for them to be land spreading or landfilling. Hence, A3 set out to solve this underutilisation issue by devoting to upcycle eggshells to their highest potentials that can be fed back to the human food and pharmaceutical supply chain. This commitment is aligned with the expectations of the food manufacturers who discharge a huge volume of eggshells on the daily basis. "*While some of them put [eggshells] on the land, other companies are sending the materials straight to the landfill […] The big problem is that they're getting pressure from people like M&S and Tesco that they've got to be environmentally friendly and prove that they're doing sensible things with their waste materials*".

Second, a government grant is a driver for case A3's innovation. Case A3 has received grants offered by Innovate UK for the laboratory and pilot projects to valorise eggshells: "*We are in a position to raise funds for a pilot plant*" (A3-1). Undoubtedly, this support is crucial for them in the early stage of the innovation where Case A3 has now been able to develop the technology that enables them to produce materials of desirable quality. They are now looking for more governmental aid in the commercial phase as A3-1 continued: "*… we're looking at equity stroke grant money to be able to do that Located in the UK if that works, we're in a position where we can go to the commercial level.*" They, though emphasising the need for government aid, mentioned the role of potential customers' commitment to guaranteeing commercialisation success. "*The trigger to do [commercialisation success] is going to be sufficient commitment from the potential customers so that we can move 50% of the output of the plant, and exactly the same at the next level when we go to a commercial level*" (A3-1). Notably, in this regulative influence, A3-2 cited an advantage engendered by Brexit regarding imported calcium carbonate: "*British governments and people in their infinite wisdom decided we were going to leave Europe … [Calcium carbonate buyers] actually ended up with pathetically another 10% on the added value price… It's not necessarily a direct tax incentive. But a result of being able to produce in the UK, we were in a position of supply, we would knock out both of those 10 per cents of duty*."

Along with two significant drivers, its engagement has been facilitated by several social trends from different stakeholders, including food manufacturers (producers and suppliers of eggshells), pharmaceutical and nutraceutical firms (customers of eggshell-derived products) and consumers.

Next, A3 was motivated by the preference of customers, particularly large pharmaceutical corporations, for recycled and upcycled materials. These corporations perceived that the pharmaceutical markets that Case A3 plans to enter swift towards higher use of recycled and upcycled materials under the pressures from consumers and funding organisations. As A3-2 explained: "*More and more corporates are actually getting interested in actually doing something about the environment… If you go into their labs, they use vast amounts of plastics. What are they doing about that? It sounds good to them recycling using recycled eggshells to make their tablets. And it appeals to the general public [....] Ultimately, the corporates will have pressure from their funding organisations, as more and more funding groups become carry*." At this stage, case A3 has been in contact with one of the big pharmaceutical companies in the UK that has recently issued their green and sustainable policies. The interviewee shared: "*We have discussions with them, and we're right where they want us to be*" (A3-2).

Finally, the last incentive stemmed from a consumer trend that drives the local produce in a more secured and sustainable supply chain. This trend appeared to be more pronounced during the COVID-19 pandemic period. As cited by the founder (A3-1), "*I think that over the last year with COVID people have actually become more aware of environmental issues. And certainly, as highlighted in sourcing from China, there is a problem with security supply and long mileages. This actually is pretty much a driver pushing manufacturing in the UK… Then you've got the Brexit* *with their flags waving to produce in the UK, which is actually quite positive for where we are, what we're all about."*

4.3.4 Perceived barriers

Case A3 has provided five barriers that prevent eggshell valorisations in the UK:

First, the mindset of treating eggshells as wastes is cited as the key barrier to preventing any further efforts in adding value to this waste stream. Interviewee (A3-1) clarified: "*As soon as you put the name of waste or word 'waste', people expect it to be cheap. And what we've tried to avoid is that we've got a product from eggshells, and it's a food product actually developed for consumption market…."* This is a clear wrong mindset that does not fit in the circular economy transition, and A3-2 called for the change in this mindset to explore the full potential of egg-shell co-products by stating: *"I think that's the critical point with any food waste recycling is to drop the word waste, replace it with co-products, and to make sure you find a market that will give you real value.*"

Second, the market entry into the higher-end markets, particularly the pharmaceutical sector, is prohibitively high. This was well framed in the founder's statement (A3-1): "*Supplements market is going to be our first port of call. It won't be particularly profitable, but the pharmaceutical market is going to be a long haul because they're very resistant and conservative. The regulations are ridiculous, but the rewards are quite high".* This also requires a deep understanding of what the pharmaceutical customers need as mentioned by A3-1: "*Unfortunately, the white powder [calcium carbonates] comes in many forms. We need to understand what size distribution they want, do they need it coated, are they using it in tablets or capsules?*"

Third, there is the financial problem that includes how to raise capital and cope with long payback periods. The valorisation project must access capital to fund the R&D and pilot-scale projects, but loans at the banks are normally not an option. A3-1 persisted: "*Going from lab to commercial is a risky place and bank funding is very it's quite difficult. People don't like to blow my funding risk*". While initial capital investment is difficult to access, it is also challenging to ensure a smooth financial flow in the transition between pilot and commercial scale until the revenue can be generated. A3-2 added to this point by saying: *"I think the main thing at the moment is making sure that we've got finance that flows smoothly. Then potentially we could end up in a bit of a black hole between the pilot-scale and commercial-scale… This is particularly challenging as the product might take time to get in a certain market, causing a higher risk. We're looking for the pharmaceutical business, but it's taking longer than we expected it to take* *on. It's really about financial planning to be able to cope with that potential extension of time before we get revenues."*

Fourth, there is a scalable technology to produce high-quality calcium carbonate from eggshells due to contamination risk. A3-2 explained: "*We discovered that we had a problem with contaminants that naturally occur in eggshells. And we'd done some chemistry to remove them. And we found that there were issues with using reagents chemicals to do this process made it prohibitively expensive"*. The interviewees in case A3 acknowledged a firm in Spain that supplies calcium carbonate made from eggshells. However, after testing the quality of the calcium carbonate materials from this firm, A3 found out that the materials cannot be used for human consumption or the pharmaceutical sector: "*We're aware of a company in Spain that does a commercial scale, but they're addressing a different market. Their material is of insufficient quality to achieve that. The process just cannot do it, we've done tests on that material that fails miserably for pharmaceutical standards. So yes, there are people out there but they're not actually just the same market"* (A3-3). As the result, calcium carbonate from eggshells at the moment cannot compete with those from the mining industry in terms of both quality and price. An efficient purification solution is required to change the perspectives of the industry towards eggshell valorisation.

4.3.5 Case summary

In summary, case A3 possesses the technology that can purify and produce high-quality calcium carbonate materials from eggshells that fit in the food and pharmaceutical market. Although the upscaling project is still underway, case A3's innovation contributes to generating higher value from eggshells by-products that are commonly discarded into landfills or spread on farmlands as fertilisers.

The drivers for case A3's engagement primarily come from (1) commitment to upcycling eggshell wastes, (2) regulative aids and partly from (3) the market trend toward upcycled materials (4) and toward local production. A3 underlines five barriers in its innovation model: (1) wrong waste mindset, (2) prohibitively high market entry, (3) financial challenges, and (4) technology scale-up challenges.

4.4 Case C1 – Valorisation of spent ground coffee

Case C1 was founded in 2013 by an architecture student at a leading University in the UK when working on a project to design more sustainable coffee shops. As the founder realised a big waste stream associated with spent coffee grounds (SCG) and no way for this huge waste stream to go rather than food waste, this motivated him to look for options to generate higher value out of this 'premium' product. As stated by Managing Director (C1-3), "*Seeing the issue with* *spent ground coffees was the sort of lightbulb moment behind your story*". Case C1 has actively engaged in new product development (NPD) and reaped success in converting SCG into three lines of products – solid fuels in the forms of coffee logs and coffee pallets, coffee flavour and fragrances (FNF), bioplastic raw materials – at a commercial scale. At present, the company processes 7,500 tons of SCG per year, employing 35 permanent staff and occasionally hiring agency staff in busy times, such as when winter hits or Christmas or BBQ season.

4.4.1 Overarching picture of the spent coffee ground management in the UK

SCG is particularly rich in polysaccharides (cellulose, hemicellulose, lignin) and protein, and it is also a good source of lipid, minerals, and dietary fibres (Ballesteros *et al.*, 2014). This chemical composition offers attractive functional properties such as water and oil holding capacity, antioxidant traits, and emulsion activity and stability. These properties offer great potential for re-utilisation in the food, pharmaceutical and nutraceutical sectors. Due to high availability at low cost and rich chemical compounds, growing research attention has been accorded to producing a spectrum of bio-based products and bioenergy in a biorefinery concept from SCGs feedstock. This is aligned with the circular economy concept that promotes a more complete recovery of high-added value compounds, such as lipid oils, polysaccharides, phenolic compounds, and tannins (Mata *et al.*, 2018; Zabaniotou and Kamaterou, 2019).

According to the interview, SCG in the UK normally goes anaerobic digester, and in some worst cases, it goes to landfill or incineration without energy recovery. *"What we're trying to address is the fact that we think there are about 500,000 tonnes of spent coffee grounds in the UK, which prior to us and other disposal routes, a lot of those coffee grounds were ending up in landfill, which is bad. This is bad for the environment because they release methane*" (C1-3). Furthermore, the Chief Operating Manager (C1-1) mentioned the perspective of AD operators towards SCG: "*Although anaerobic digestion is favoured, unfortunately, the people who run the AD plant don't necessarily like coffees any large volumes… because they do not work very well in anaerobic digestion, it's very difficult to regulate*."

4.4.2 Circular economy practices

Case C1 is the first mover in this market that looks for better use of SCG in terms of environmental performance and economic value. Case C1 has successfully upscaled the technology and designed the new supply chain for the novel SCG-derived products. Case C1's practices in terms of procurement, operations and technology, products and markets are illustrated below (Figure 10).

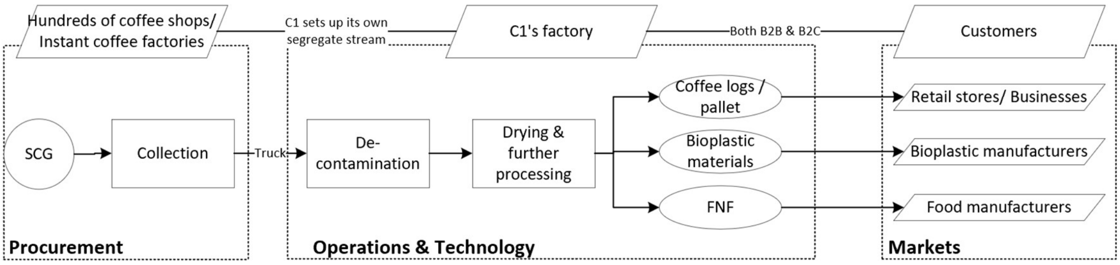


Figure 10: Circular practices employed in C1

Source: Created by author

As for procurement, SCG is collected from two main sources: big UK coffee chains (including coffee brands and fast-food chains) and regional waste recycling companies. Regarding the collection at coffee chains, Case C1 has designed the most cost-effective way of collection. Each day, each chain delivers fresh goods like bakery goods and coffee beans to its store, then collect SCGs and paper cups from the previous day to go back to one or two distribution hubs. SCGs are sometimes mixed with food waste, plastic waste, and cardboard. Those hubs are equipped with big containers of case C1. Once containers are full, hauliers pick them up and move them to case C1's processing plant. Some big suppliers have daily collections of multiple tons. That's the most cost-effective way of collecting SCGs. Regarding collection at regional waste management companies, these firms normally collect SCGs along with plastics and coffee cups and aggregate them in a few places. From here, waste management firms transport full truckloads of SCG material to the processing site of C1. This step is considered the biggest part of the process to get the coffee as efficiently and clean as possible.

As for operations and technology, once SCG arrives at the site, it goes through the decontamination and drying step. The first job is to decontaminate the SCG because sometimes the waste stream is mixed with occasional banana skins or carton boxes. Then, SCG which often comes with 60% moisture, is dried to reduce moisture level down to 10% by a biomass dryer. The dryer is proven to be a carbon-neutral means of drying SCGs. The output of this process is a raw, refined, decontaminated, dried material. After that, case C1 determines where these materials go in one of three routes: solid fuels, bioplastic materials, and FNF. If it goes to FNF production, the materials will need to be distilled using the proprietary green extraction methods. The production decisions among these product lines are led by commercial forces as underlined by Commercial Head (C1-2): "*We have projects in place that are changeable depending on market demand, if we've started looking at that particular avenue and it doesn't seem like it's going to be a commercially beneficial end product, then we will not continue with that".* However, majority of SCGs go into the solid fuel market or bioplastic material market. C1-3 supplemented: "*So we've got this constant juggling act between feedstock, the amount of* *coffee grounds coming in. And, and so we can wait. If we build too much demand for the product, we probably won't have enough feedstock. If we don't build enough demand for them, we can have too much. So yeah, it's quite a complex model*".

As for the market, case C1 has three product lines that go into the following markets:

First, solid fuels in terms of coffee logs and coffee pallets (B2B model) follow B2C and B2B business models respectively. Coffee logs are nicely packaged to be sold in several big supermarket chains and garden centres in the UK where end-consumers can buy and burn the coffee logs in their houses. Coffee pallets are sold for businesses, such as crop greenhouses or industrial boilers where a lot of heat from burning coffee pallets is required.

Second, biomaterials are mainly sold to the manufacturers of brake pads and -plastics to replace the use of conventional fillers in brake pads and petroleum compounds in plastics. These versatile and sustainable raw materials are consistent in particle size moisture content and bulk density, which displaces the need for virgin or synthetic materials that can be used in a range of industries from bioplastics, automotive parts, and cosmetics to textiles. This contributes to emission reduction and sustainability achievements.

Third, FNF that is used as natural flavouring ingredients in foods and beverages are sold to the flavourists, formulators and food manufacturers. It is estimated that a third of the volatile aroma and flavour compounds in fresh coffee remain in SCG, which offers significant value if can be utilised for FNF extraction. Hence, case C1 is working on fully realising its value in FNF extraction.

In addition, case C1 has continuously strived for more innovations in SCG extraction because SCG still contains a high proportion of natural chemical compounds that have not been fully realised up to date. These compounds offer a wealth of industrial and commercial applications from oils to dyes to antioxidants and even proteins.

4.4.3 Perceived drivers

Interviewees at case C1 perceived its authentic commitment to upcycling SCGs, government funds, and a strong market incentive for SCG-derived products as three crucial drivers for their engagement.

First, interviewees in case C1 consistently underlined that the genuine aspiration to find a better use for SCG, which is also aligned with the circular economy thinking, is the main driving force behind its business model. They realised the huge potential in this premium SCG stream and its suitability in the circular model. C1-1 stated: "*I suppose why we want to do this is because we believe that there's more inherent value in that coffee than just going to anaerobic digestion. So,* *even though it was favoured to go to anaerobic digestion. The business idea and models have way more value in these coffee grounds…".* C1 expected that their success will help more and more businesses to follow suit in the near future as stated by C1-3: "*I'm hoping that there is more and more, there is a better case for valorising to those that would otherwise have gone to waste. And I think a lot of that by design procedure for waste*".

Second, case C1 secured several capital grants from the local funds for new business innovations in and around agriculture and food, and from Innovate UK for the research on the potential use of SCG. Commercial Head (C1-2) mentioned: "*All grant schemes have encouraged us to research and look for greater value in the coffee grounds. For example, the Innovate UK grant provided funding for us to look into the potential end-users of SCG, which are flavour products and buyer-made materials. So that's been helpful from the government*."

Third, there is a strong preference for upcycled materials made of SCG. C1-2 explained: "*It's great that coffees are being reused like this. I think that is key in people's minds when they're buying the product. They are doing something beneficial here by burning a coffee log*". As coffee is so popular in the UK, coffee drinker expects to see large coffee brands be more sustainable by doing something useful out of their waste stream. C1-5 justified: "Y*ou're a coffee drinker, you want to know if this company is doing something with spent coffee grounds rather than just, you know, letting them go to waste".*

Along with these fundamental drivers, C1's operations have also been stimulated by a blend of two additional factors:

Fourth, case C1 emphasised the impact of the upcoming plastic tax law as a driver for the plastic manufacturers to look at recycled plastic materials made of SCG. Managing Director (C1-3) specified the impact of the upcoming plastic tax: "*We've got plastic tax coming, which is quite interesting. Because suddenly, all the plastic manufacturers are going to be forced to be using, you know, no less than 30% of recycled renewable material. Otherwise, they get charged 200 pounds per tonne*." In this vein, Commercial Head (C1-2) added that a more expensive landfill tax and a ban on certain products are the other factors driving SCG valorisation efforts. "*The government banned wet wood. Yeah, so that's good for us because it means that there are fewer competitors for coffee logs, so that's something the government's done*".

Fifth, technical supports from non-governmental parties play a part. The Chief Operating Officer (C1-1) emphasised the facilitating role of the organisation such as WRAP: "*So I think that's the third sort of piece about government is WRAP…. WRAP has been engaged with us in the last 12 to 18 months, but they've really helped us as almost an impartial kind of business… WRAP is a* *sort of an independent business and knows this stuff inside out. They're much better than the government because you can't really phone the government up and ask them what their laws be. It's very hard to talk to people in government*".

4.4.4 Perceived barriers

Case C1 provides the following lists of institutional barriers that they perceived:

First, case C1 suffers the bureaucratic regulations governing end-of-waste as case C1 operates in the business that extends the end life of materials. Chief Operating Officer (C1-1) expressed: "*Unfortunately get caught up in a lot of bureaucracy in UK legislation. Spent coffee ground is classified as waste, so if it is used to make another product, the processor like us needs to prove that product is useful and safe to use following the end-of-waste legislation*." At the time of setting up the business, case C1 has to go through all sorts of end of the waste process to prove that case C1 is not still selling waste and that end-products are useful and safe. C1-2 expounded this point: "*Every usage for that material [SCG], we've got to complete end of waste certification for it. Certification is quite long because the government wants us to prove that what we're doing with it, and what's going to be done with it is good. That is very tricky legislation for us to navigate and get sort of the stamp of approval. It's just sort of a bit of a grey area really at the moment.*"

The second barrier comes from the legislation for solid fuel products. The government has brought out two schemes around air quality: eco-design standards and safe-to-burn ratings. To get accredited for eco-design, case C1 needs to have its products tested in multiple stoves available on the market to see how solid fuels perform in the stove. However, there are thousands of stoves on the market and each test costs 3000 pounds. The expensive costs have presented case C1 from proving that its product is as good as woods. For safe-to-burn rating, case C1 has not been allowed to get that rating because that standardisation is only applicable to wood products. Hence, case C1 needs to lobby the government and get the data to show the emission levels from coffee logs.

Third, the regulation made the AD become the default acceptable waste recycling landscape in the UK as claimed by C1-2: "*In the UK, AD has been quite heavily subsidised as a route to sort of taking up the large volumes of by-products and food waste. That is there for kind of almost the default scene as just the acceptable good place in which food waste can go to. This seems to miss some of the nuances to really engaged with opportunities with feedstocks to do more*." This causes competition for the SCG feedstock with AD despite the fact that AD does not perform particularly well in digestors. C1-2 added an associated problem with this subsidy landscape:

"*There was a bit of competition for the feedstock. Anaerobic digestion sites take the coffee and sort of subsidise to chase after feedstock. So I don't think that's a hugely helpful landscape*"

Fourth, there is no segregated waste stream existed in the case of SCG that prevents the collection of clean materials for further processing. Instead, SCG is viewed as generic food waste and often mixed with other types of waste to be recycled at AD plants. The Managing Director (C1-3) explained: "*Getting people and the coffee shops providing us coffee requires a segregated waste stream and to not just throw it in with their food waste is kind of is an ongoing challenge for the business because we need to give them the incentives and the rationale, and the reason to want to go and do that."* Commercial Head (C1-2) illustrated this further by comparing this waste stream to other waste streams: "*There is no segregate waste for coffee. From day one, it wasn't the waste stream that exists. It wasn't like clothes or something if you want to set up a business recycling clothes in the UK, that sort of waste stream exists already."* This represents a real challenge for case C1 as it must create a new segregated stream and change the behaviours of actors in this chain.

Fifth is the market entry in the solid fuel business. Case C1 encountered the market barrier to enter by sabotage action of an incumbent firm. Chief Operating Officer (C1-1) recalled: "*There is one very big incumbent firm that holds the majority of the UK solid fuel market. We cannot say for sure but we definitely see evidence that they kind of discredit coffee logs so that they sort of block us from getting our products to the market as quickly as we want to. So, yeah, all those problems I think of being something new in a market."*

Sixth, case C1 encounters challenges to convince SCG suppliers to sell SCG for them rather than AD. The current waste hierarchy prefers AD over solid fuel generations. Chief Operating Officer (C1-1) supplied an interesting point from the conversions with the SCG suppliers. C1-1 recollected the narrative of the SCG supplier: "*Well, hey, isn't what you're doing just energy from waste. And the energy from waste is down here on the waste hierarchy, but AD is higher up. So we want to go as high and we want to go as high in that hierarchy as we can. So why would we give coffee to you, if you're below our current usage which is anaerobic digestion".* Hence, case C1 had to knock on these customers' doors to disprove these customers' arguments from the waste hierarchy by conducting carbon footprint analysis. Commercial Head (C1-2) cited: "*We've sort of used carbon footprint analysis and stuff like to really justify that they save more CO_2 if their coffee is reprocessed by us than put into AD. So that's been another challenge for us*."

Seventh, there is a lack of market mechanisms for the end products. A linear business is often set up based on market demand. However, firms in the waste valorisation business start with the waste stream and then find the market to sell the output products. C1-2 elucidated this problem: *“Because the business was driven by the existence of the wastes, not by not really by a clear market for an end product from the wastes, starting the business had been the challenge and we spent the time trying to find the end product. Where it should really go is where's the opportunity in the market, what's the product, how do we. That's normally how you set up businesses”*

Finally, technological scale-up has been identified as the key challenge for the engagement in the SCG valorisation because SCG is very sticky and difficult to clean, dry and process. C1-2 described this problem and at the same time specified case C’s future development: “*We think we've got some pretty good know-how barriers to entry because it's not easy. We’ve spent years painstakingly developing our supply chain and proprietary decontamination and drying technology to renew large volumes of spent coffee for reuse…We don't expect a competitor to emerge in the UK, trying to do what we do... And we would either licence our technology to somebody else, overseas, or probably, we would seek to set up a business in Europe to do similar to what we do in the UK, and so that all sort of replicate what we've got here”*

4.4.5 Case summary

In summary, Case C1 processes SCG to make three types of products, solid fuels (coffee logs, coffee pallets), bioplastic materials, and FNF. While coffee logs are available in the market for consumers to buy, the remaining product lines are sold to business customers. In the UK, SCG is commonly fed to AD plants for biogas or landfill without energy recovery. Case C1’s innovation has contributed to more sustainable and efficient management of this waste stream.

Case C1’s innovation has contributed to more sustainable and efficient management of this waste stream. Case C1’s innovation came chiefly from (1) commitment to upcycling SCG – the last puzzle of sustainability in the coffee supply chain, (2) regulatory grants, and (3) a strong consumer preference for upcycled products from SCG. The effort derived partly from (4) changes in plastic tax legislation and (5) technical supports given by WRAP. Eight barriers are identified, which include (1) bureaucratic end-of-life legislation, (2) expensive standardisations for end-products – solid fuels, (3) regulations supporting AD as a default landscape, (4) no segregated SCG stream, (5) high market entry in solid fuel business, (6) over-reliance on waste hierarchy, (7) a lack of market mechanisms, (8) technological scale-up challenges.

4.5 C2 – Valorisation of potato peels

Founded in 2017, Case C2 focuses on turning food manufacturing by-products into durable plastics that are compostable, degradable and recyclable. Its mission is to find a sustainable material to cope with a lack of materials in sustainable design and the issues of an enormous volume of materials waste in design and fabrication projects while simultaneously making better use of agricultural by-products. As shared by C2's co-founder (C2-1): "*It actually became increasingly aware to both of us that through the design practice, we have to use a huge amount of materials, not just on the product themselves but the off-cuts and the trims and everything else to create the product… We see ourselves as problem-solver so most directions we take from trying to find another solution for the problem that we are having*".

C2 had initially looked into the production of Medium-density fibreboard (MDF) from potato wastes for around one and a half years, but it has now transitioned to biopolymer production. "*We are going for four and a half years now. At the start of exploration, we are looking into alternatives for the materials we are using in the environment […] So originally, we were looking into an MDF substitute, and that was all focus of our research for the first year and a half. We've now transitioned over to polymer so making plastics from food waste"* (C2-2). After more than two years of actively engaging in R&D in this area, C2 has successfully upscaled its technology to convert agricultural by-products such as potato peels and olive wood flour into thermoplastic that possesses characteristics of normal plastics while easily degradable and responsible, thereby shifting the materials from technical to biological cycles. The current production capacity is one ton of output materials per day and the end products can compete effectively with other bioplastic materials in terms of quality and price. This is not a huge capacity at the moment, but this enables C2 to fully realise its end-to-end process and demonstrate its production scale.

4.5.1 Overarching picture of potato manufacturing waste in the UK

Potato processing industries such as fries, chips, hash browns, puree and frozen foods discharge a huge amount of bulky waste in the form of potato peels that account for 15% to 40% of the fresh weight of input materials (Schieber *et al.*, 2001). Potato peels have a high content of starch, dietary fibres and protein. Thanks to this chemical composition, potato peels have attracted vast interest in the research community over the past few years (Sampaio *et al.*, 2020).

The interviewee gave an estimated figure of roughly 100,000 tons of potato waste generated in the UK alone and one million tonnes worldwide. Interviewees further mentioned three common routes that this waste stream currently ends up with, which include: anaerobic digestion, low-grade animal feed, and landfill. "*This mountain of potato peels that went to waste to produce those snacks […] So it's important to say that there are existing streams and existing options to put this waste such as landfill or anaerobic digestion or extremely low-grade animal feed. So there are traditional options where this goes but there's been a low value associated with this* *waste, which is a massive shame.*" (C2-1). C2-1 also elaborated that the reason for low-grade animal feed comes from the low-nutrition value found in the potato by-products.

Except for these three common routes, case C2 is not aware of any UK-based firms that offer similar innovative solutions to valorise food by-products. "*Other companies are using other waste streams to make plastic films, leather, alternative. So there are some really interesting projects out there looking at utilising wastes to solve a lot of problems within the fashion industry […] but there's no one else producing PLA which we produce made solely from waste*." [C2-1]. Hence, C2 is the pioneer in waste-based plastic production that adds values to the feedstocks that are not currently able to valorise.

4.5.2 Circular economy practices

Similar to C1, C2 is the first mover in the UK market that looks for the production of plastic materials from waste streams. The case has successfully upscaled its technology and run a simple supply chain in the by-products-based bioplastic market. C2's procurement, operations and technology, end products and markets are presented below (Figure 11).

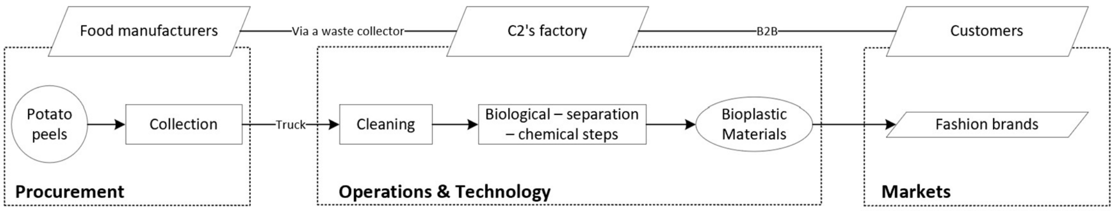


Figure 11: Circular practices employed in C2

Source: Created by author

As for procurement, C2 used to work directly with one big potato chip producer and still maintain a good connection with them to get the nutritional data and other useful data about their waste stream. "*One of the partnerships that we're very proud of is that we work with one of the largest potato producers globally. We use everything that they do not use to create our product, so we are not using anything that has a purpose to go into production. What we are doing is truly a by-product*" (C2-2). The waste stream comes through a third party, a company that works with manufacturers on the logistics and distribution of waste streams in industrial food manufacturing. Although C2 only acquires one waste stream, potato peels, from this company, this collaboration allows C2 to easily plug into and explore other waste streams in the future. In terms of costs, C2 paid for materials and logistics costs associated with this waste stream. C2 was not able to extricate the price paid but C2-2 commented: "*It's extremely cheap, you're paying a penny per ton*".

As for operations and technology, R&D is the core of its process so C2 run its own R&D department to expedite the process. "*We have an extremely talented group of people that are here full-time, so we have three different departments, biochemistry, polymer chemistry, and chemical engineers. So really every section of our process is covered with R&D, which allows us to work very quickly in-house. We often work with universities and outsource projects. Obviously having in-house R&D allows us to make changes and make decisions and obviously get results a lot quicker*" (C2-1). C2 use proprietary technology processes to produce bioplastics and composites from industrial food wastes. By-product peels come directly from factories in big barrels. At C2's factory, these materials go through a series of biological and separation and chemical steps without the use of toxic materials or solvents until the final materials that are compostable, recyclable and can be processed using traditional plastic manufacturing equipment are produced. The entire production process is self-contained as materials move from farm to factory and then to consumers. Once the end products reach the end of their life span, they can be then sent to an industrial compost plant and ready to become fertilisers used on the farm.

As for product and market, C2 produces thermoplastic from potato wastes at the moment. Thermoplastic comes in pallet form for inspection moulding, extrusion, 3D printing, or other similar purposes. It utilised wasted peels from the food processing industry as a low-cost feedstock to produce thermoplastic that can be used in the fashion industry, such as sunglass frames. "*At our company, we want to make sure that we still have plastics that we need, and they do not have conditions of petrochemical plastics, but they are biodegradable, recyclable and overall responsible. If a heart valve is made of biodegradable plastic, I can reassure you that what they use in those applications is incredibly versatile and will last forever.*" (C2-4). This material offers three key advantages in terms of front-end and back-end environmental benefits as well as price competitiveness. First, it is made from food by-products that would otherwise go wasted. Compared to similar biomaterials made of virgin feedstocks such as sugar cane and corns, food by-products do not require the use of land, water and other resources. Hence, the utilisation of a waste stream in the case of C2 massively negates this front-end effect on the planet. Second, the material offers the benefits of being biodegradable, compostable and recyclable while its pallet forms contribute to a circular manufacturing process with no excessive use of waste. Compared to petroleum-based plastics, bioplastics do not negatively affect the soils because it does not bleach oils and toxic chemicals into the environment. Its pallet form is ideal for injection moulding, a sustainable way of producing without any offcuts so manufacturers just need to use the exact amount of plastics required to create parts and products. Third, the material is priced competitively against other bioplastics in the market. "*We don't believe in overcharging against* *current manufacturing and also sustainability as well because for brands to transition to an alternative that needs to make financial sense on their side. So really, it's a balancing act. It's basically juggling how we can obviously maximise the cost of the amount that we're selling our product for, but also making it viable for purchasers in various industries to make it viable for that product." (C2-3)*

C2 mainly sell thermoplastic materials to the fashion industry for two reasons. The first reason comes from a market mechanism with a strong demand pull emanating from this market. As explained by the interviewee, "*It was just the people that are approaching us the most. So yeah, I get a lot of emails from the industry. I'd say 70% from fashion and obviously snowballs because we work with fashion. There are articles written about us regarding fashion and then get involved so they're just purely down early on. We were getting each other interest from brands within fashion*" (C2-2). The second reason comes from the pressing sustainability pressure in this market. "*We have an incredible amount of draw from fashion, the reason for that comes from human pressure on that industry. Our materials are fantastic for products that need to be able to live a life but when you finish with those materials, we ensure that they are disposable responsibly"* (C2-4). C2 also emphasised the versatility of its thermoplastic materials that can easily fit in other industries, including but not limited to consumer electronics, interior design, and medical sectors. "*There are obviously huge amounts of plastic being used in every walk of life. So really, we can explore a lot of them.*" (C2-3).

Notably, C2 offers durable thermoplastic that can be used for long-lasting products rather than single-use plastics because the single-use plastic problem originates from the convenient lifestyle of modern society rather than the plastic material problem itself so biodegradable plastic is not a solution for this issue. Interviewees also urge the need of altering consumption habits. "*Plastic is sturdy, durable and it lasts forever, which has both good and bad sides, but it is the throwaway culture of plastics. That's where the real issue is and if you're able to redesign the way people use plastics like carton straws. That makes sense. There is an overwhelming need to look at the plastic issue within single-use. We do not think our materials are solutions for single-use plastic. Rather, our materials are used for things that have a life based around trends and the lifespan of a product being designed within it. We've done some collaborations with fashion*".

4.5.3 Perceived drivers

C2's engagement mainly comes from three following factors:

First, C2 was driven by the commitment of two co-founders to invent a new material that can solve the plastic problem – a pressing sustainable issue of modern society sustainable issue –

and upscale food manufacturing waste. *"Our intention is to address food waste and plastic issues. These currently pose a major challenge to the environment […] Sustainability is the core principle our company was founded on and is the driving force behind our need to improve the world we live in* […]" (C2-2). This commitment directly led to the creation of C2's new sustainable model building on the abundant 'waste' resource rather than tapping into virgin materials. Not only taking the by-products discharged from other sectors and adding higher value to them, but C2 also offers a radical solution to tackle its own waste. "*We have a zero-waste mindset. What happens is that we take that by-product we can put it through our process but there are also parts of that feedstock that we cannot use in our process. Once we've taken what we need we can actually continue what we do not use in the same stream (animal feed). And actually, what we do not use is a much more refined animal feed which is actually better for animals in the long run anyway so actually we can plug it into a current logistics system which is a factory by-product to animal feed. We can valorise part of that by-product to create our materials but then still maintain that feed. So, we do not actually take anything from one industry or another*" (C2-1).

Second, government support in form of grants allows C2 to transform its idea into a successful project. Markedly, interviewees claimed that the UK government offers no running scheme designated for food waste valorisation but C2 is able to tap into generic innovation schemes thanks to its novelty and contributions.

The last driving force that has been mentioned during the interviews is the social trend toward sustainability in the market. This is a real impulse as the consumers are powerful in shaping where the market goes. "*As the world has increasingly become more environmentally aware, along with commitment towards green energy and clean technology. We see that our technology can fill the void and create an efficient sustainable business model."* (C2-1) As mentioned earlier, this sustainability trend is pronounced in the fashion market as people are increasingly conscious of their purchasing decisions of sustainable apparel and textiles. "*More and more people want to acquire products from sustainable e.g., recyclable materials but also made to last. Production costs using sustainable materials around one and a half times higher, and customers do pay a premium but despite that, sales have grown by more than 50% over the last few years.*" (C2-2). C2 estimated that by 2025, sustainability would be a significant factor for consumers purchasing mass-market apparel.

4.5.4 Perceived barriers

During its engagement, a number of barriers have been underlined.

First, technology scale-up with lengthy R&D is the most pressing barrier expressed by all interviewees. As explained by C2-1: "*Time being so obviously, coupled with other events like*

COVID starts in the middle of our operations wasn't the best thing in the world in terms of in terms of the enrichment KPIs [...] Again, time is the barrier in terms of there's so many tests and projects that our staff can do in a day" (C2-3). This is particularly important when working with new materials as their customers need time to test C2's materials. "*The bigger barrier is that there's a very specific type of industry that can use the material and others can't, maybe directing where the tool goes might change slightly in the future [...] A lot of customers have different requests in terms of what tests are needed. We are working with customers to make sure that we have the right information about our product as well if needed*" (C2-4).

Second, finance is another significant barrier for any start-up including C2. "*How to secure finance to make sure we haven't made to keep going but also spend enough to make sure we're getting the random of staff in the right equipment in so it's a big juggling act. So really, there are bad real barriers that we have*." Despite being an apparent driver of their success, finance is pointed out as a huge barrier that challenges C2' operation. To overcome this challenge, C2 also needs to constantly tap into different resources. "*We're always looking to regional and national grants because we're always looking for more. Yeah, it's about its balance between investment and grants as well*" (C2-5).

Third, the psychological barrier could prevent other companies to work with food waste and by-products. This barrier acts as a hindrance preventing firms from engaging in the first place. "*I'd say it's quite a messy job in terms of obviously everyone likes working with lovely clean ingredients and stuff like that. But I think whilst there is the initial messier element, which is the cleaning and sorting of these by-products, the environmental benefits, in the long run, are just exponential compared to existing processes. So we're able to get the messy work done. A process for that but in place, then obviously, that's a good thing for everyone*." C2 emphasised the need to overcome this psychological barrier in order to diffuse the circular practice in the food waste management area. Similar to A1, C2 also called for the changes in the name of food waste. "*We do not like to use the word 'waste' but we use the word 'co-product from food industry so things for otherwise would go to waste because the word 'waste' could make people see it as an unused or mismanaged resources. In our case, we can produce a product that replaces petrochemical plastics while giving value to it"* (C2-3)

In general, lengthy R&D and fundings are two main barriers, followed by demand variety and psychological barriers in working with waste. Apart from these barriers, C2 expressed its optimistic perception of the overall operations. When asked about other possible challenges, all interviewees in C2 do not raise any concerns over the security of sourcing and regulation barriers to the introduction of waste-based biomaterials. In terms of sourcing, C2 has protected itself by signing a long-term contract with the food waste management company to secure a constant supply of its feedstock. Seasonality is not C2's concern in the case of potato waste as cited: "*We do not encounter seasonality because large industrial food processes do a lot of the seasonality themselves. For example, [a large chip producer] always has food waste coming out. That's the same consistency. Yes, there's crop seasonality, but they're the ones that have dry storage and cold storage to ensure that they have their supply chain all year round. They already understand the seasonality for them to make sure they've got the product*" (C2-4). In terms of regulations on waste-based biomaterials, the co-founder of C2 expressed that he, though acknowledged its bureaucracy, did not put it as one of the immediate challenges because the regulations for bioplastics are less strict compared to other industries such as pharmaceutical or nutraceutical sectors.

4.5.5 Case summary

In summary, case C2 engaged in searching for sustainable bioplastic materials from food manufacturing by-products such as potato peels. When potato peels commonly end up in three routes, AD, animal feed and landfill with little or no value creation, case C2's innovation effort leads to higher value retention for this waste stream while solving plastic issues in the modern society.

Its engagement is driven by three factors: (1) commitment to upcycling by-products and solving plastic issues, (2) availability of government funds, and (3) market preference for upcycled products. During its engagement process, it encountered four barriers (1) technological scale-up with a lengthy R&D period, (2) financial constraints, and (3) psychological fear of working with waste.

4.6 C3 – Valorisation of pineapple leaves

Launched in 2016, C3, a London-based company, was a pioneer to produce naturally made alternatives for leather made of pineapple waste. C3 was founded by a designer who was shocked by the appalling conditions in leather tanneries during her consultancy works in the fashion accessory industry many years ago. The founder decided to embark on the journey to look for plant-based fibres that can solve the environmental and ethical issues in leather production. After seven years of independent research, the founder successfully invented natural, sustainable and cruelty-free materials from pineapple wastes at the laboratory scale. This success led to the establishment of C3 in 2014. Another two years were paid to launch its product to the market and set up the supply chain to reap the commercial success. At present, C3 has supplied to hundreds of brands in the fashion, upholstery and automotive sectors globally and thanks to the versatility of its material, C3 will continue to expand its presence in other industries. The weekly production volume at the time of interviews is 5000 meters and employs thirty staff in three countries in Asia and Europe.

4.6.1 Overarching picture of the pineapple wastes in the UK

According to interviewees, as the second most popular fruit, the pineapple industry discharges around 87 million tonnes of leaves during harvesting operations. This huge volume of waste is usually burned or left to rot in the field because farmers do not know what to do with this massive scale. These practices are not only environmentally harmful but also a waste of a resource that violates the core concept of the circular economy. As interviewee (C3-2) explained: "*It is a huge amount of leave wastes. A bit is used for animal feeds, or another bit is used for fertilisers, but I could say it is less than 15% so more than 80% is getting wasted [...] so we use the leaves of the plant which is one meter long and nothing to do with the pineapple fruits that go to the food industry, not even the crown*".

Pineapple is a great source of fibres. For hundreds of years, the local community has hand-woven the fibres from pineapple leaves to create beautiful garments, which inspires the founder to look at this material. However, none of the scalable production had been captured until the establishment of C3. C3's founder made a new way of using this fibre. C3 invented a novel process to extract cellulose fibres from these leaves and create vegan leather that shares desirable traits for the fashion industry, including durability, water resistance, breathability, and sturdiness.

4.6.2 Circular economy practices

C3 was the first company that possesses a patent-based process to produce vegan leather made of by-products that would otherwise go wasted. C3 has invented a novel process and designed a new supply chain to scale up this process. Its procurement strategy, operations and technology, as well as products and markets are elaborated below (Figure 12).

As for procurement, C3 organised the acquisitions of long fibrous leaves from pineapple farmers. The collection activity was a real challenge at first because nobody ever acquired these leaves before, so C3 needs to organise and set up the inbound supply chain to acquire materials by themselves. In addition, C3 works with cooperatives and trains their farmers to use C3's machinery so farmers can involve in the early processing stage while getting an additional source of income. In July 2021, C3 initiated a collaboration agreement with one of the largest fruit and vegetable producers in the world to source pineapple leaves. The inbound set-up of small farmers and a large corporation contribute to creating a wider positive social impact on farming communities by generating more jobs and additional revenue streams while driving down the carbon footprints owning to valorising waste at scale.

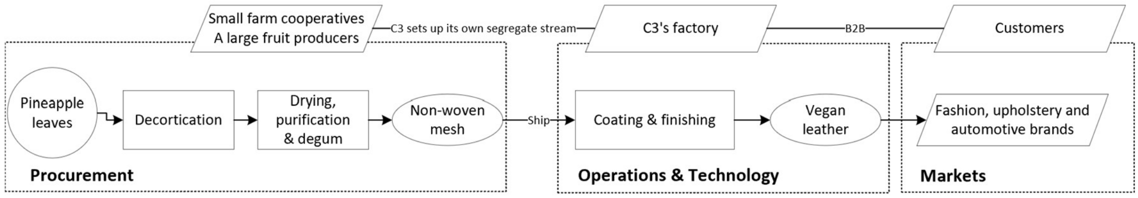


Figure 12: Circular practices employed in C3

Source: Created by author

As for operations and technology, the operations of C3 can be divided into two major stages: base processing in the pineapple harvesting country and the finishing stage in the EU. *In the base processing*, farmers collect leaves and extract the fibres from the leaves using a special machine called decortication offered by C3. At this step, leaves are stripped of their fleshy surface biomatter to retain only long tough fibres that form the base for its vegan leather. These fibres are then washed, dried, purified and degummed to remove pectin and produce soft and cotton-like materials. To ensure sustainability and create an authentic circular economy transition, no toxic chemical is used in the process while the green biomass residues from the extraction stages that contain all nutrients are utilised as fertilisers for soil improvement in the local community. Next, the cotton-like materials go through a series of spike rollers to mix and bond together using an industrial mechanical process to create non-woven sheets. *In the finishing stage*, these sheets are shipped in rolls to a central plant in Europe for further processing using textile finishing technology such as lacquer-like coating to be transformed into a new vegan leather. Since its commercialisation, C3 has continuously invested in R&D to reduce the environmental impacts in the finishing stage such as the incorporation of plant-based resin. On average, the production of one square meter of this novel vegan leather needs 480 leaves or 16 pineapples.

As for products and markets, C3's vegan leather has necessary properties that meet market requirements including strength, durability, robustness and water resistance. Compared to leather skins, it is 30% cheaper in price, lighter in weight and most importantly, more sustainable thanks to its 95% plant-based in a transparent supply chain. These are all desirable by the customers in the fashion and upholstery sectors. The material has been used to make shoes, bags, wallets, clothes, and furniture.

4.6.3 Perceived driver

The main drivers for the establishment of C3 came from the commitment to solve the sustainability issue and upcycle food waste, the accessibility to the government grant, as well as consumer preference for sustainable materials.

First, C3 was directly driven by its founder's dedication to searching for a new leather alternative material while upcycling pineapple leaves. For C3, an authentic commitment to move forward is a genuine key that leads to its establishment and current success. "*We started because of the willingness of people […] You need to have a lot of determination and incredible trust. That's how it is when you want to develop something new" (C3-1).* Working in the leather industry for about fifteen years, C3's founder becomes increasingly conscious of the environmental problems associated with leather production and chemical tanning. The founder claimed that the fashion and textiles industries are some of the worst offenders for environmental and social impact. The leather industry, in particular, is notorious for the use of heavy metals and toxic chemicals such as cyanide, lead, and aldehyde in the tanning process, which jeopardises the environment and workers' health. Existing alternatives such as PU and PVS fail to reduce the environmental damage. There is a pressing need for societal change, particularly in terms of water consumption and unfair working conditions. This awareness had driven its founder to actively search for a new solution from the abundant by-products in the FSC. C3's founder tested a variety of by-products including banana and agave leaves. It was until pineapple leaves that the plant-based vegan leather was generated. This material offers three clear-cut benefits. First, this vegan leather is made in a heavy chemical-free process that is eco-friendly to habitats and people involved. The production process also performs better in terms of water and energy consumption. Second, the material is biodegradable, which again offers additional environmental benefits compared to the recycling of synthetic materials. Third, in terms of quality, the material is highly versatile thanks to its breathable, flexible and durable traits and has been used by famous fashion brands in a range of products including clothes, shoes, other accessories, and upholstery markets. Further, C3 realised that pineapple leaves in an enormous volume have currently been wasted. Thus, it is committed to upcycling this 'waste' resource in accordance with the cornerstone of the circular economy. Company expressed its view on the concept of waste: "*There is not such a thing as waste. It is the perception that we have in the mind what is waste. Anything can be useful*" (C3-3). To summarise, this driver can be well framed in the statement of the founder: "*As a designer, my objective was to create a product that carried social and ecological responsibility throughout its life cycle, and through it, do something about how to sustain and indeed to heal planet earth through our actions, at the same time than helping the pineapple farming communities where the pineapple fibres come from today… the material represents a sustainable solution in the face of today's social and sustainable dilemmas*." (C3-1).

Second, a government grant is a crucial driver that facilitated its establishment and speeded up its commercial success. In collaboration with a renowned university in the UK, C3 was awarded a grant from Innovate UK for its R&D in improving the quality of its product in 2017. This also contributes to enhancing its brand image and its material has quickly become one of the most recognised brands in the sustainable fashion industry.

Third, strong uptake in customers' interests in sustainable fashion generated a real impulse for C3's establishment. Interviewees captured a change in consumers' mindsets that care more and more about the process of how, where and when the clothes are made. Previously, the acceleration of fast fashion favoured quantity over quality. Unbeatably low cost is the main advantage of synthesis materials acrylic, nylon, polyester and polypropylene. There is a societal change that empowers the pineapple communities to make changes in their consumption patterns. The uptake in interest in sustainable fashion comes from the growing awareness of the harmful impact of the fashion industry on the environment and on its workers all along the supply chain a much larger volume of pineapple leaf fibres, to meet the ever-increasing demand for vegan leather not only in fashion but also in the upholstery and automotive sectors. Further, C3 explained how supportive customers show to this vegan material because it comes from the earth, it goes back to the earth, and it does not harm anything in between because no toxic chemical is used.

4.6.4 Perceived barriers

The interviewees in C3 boldly stated three following barriers during its engagement and journey to a circular economy creation:

First, the technological scale-up challenge with lengthy R&D was a pressing barrier for C3 to produce the new material from pineapple by-products and upscale this process. C3-1 commented: "*the scaling up of the technology is always a barrier. So, it's like working in the lab, the same prototype and then in industry, so that is a long journey*". It took seven years for the founder to find a way to produce the leather-like fabrics from pineapple leaves at her own laboratory. "*Lot of our customers used to work and still work with petroleum-based fibres which are very much easier, more even and stronger […] It took us a couple of years to come up with a mesh that was not falling into bits and meets the industrial standards for fibres*" (C3-2). Another two years were spent on upscaling the process to start launching this material to the market. interviewees also elaborated on some R&D challenges that C3 encountered. For example, C3 mentioned the problem with the use of coating materials that was not solved in the first launch. "*The coating initially consisted of 40 per cent petroleum-based resins, something we wanted to avoid at all costs for ecological reasons. However, we had to launch the product anyway because if you do not launch the product, you do not test the market, and you cannot go anywhere. We are not just in a laboratory trying things […] After several years of development work, we succeed* *in reducing the proportion of petroleum-based resin to five per cent without losing the leather-like quality* (C3-3).

Second, the financial hurdle is pointed out as a direct result of a long technological scale-up. Further, although C3 receives several grants from Innovate UK, government grants generally focus only on the R&D stage, not the commercialisation phase. Fortunately, thanks to its innovative approach and undeniable impacts, C3 has secured new funding for its expansion on a larger scale.

Third, C3 experienced difficulties in setting up its inbound supply chain to purchase and collect the pineapple leaves as there is no segregated stream for that existing in the pineapple growing countries. As underlined by C3-3: "*You cannot go to buy tons of pineapple leaves because it does not exist. It is not a commodity. So that's the next thing. We have to go and do the supply chain ourselves. This is the biggest headache ever… It's incredible because one thing is to develop new material and the other thing is actually to develop a supply chain*".

Fourth, a lack of market mechanism is listed by interviewees in case C3 as a barrier that has been overcome by C3 thanks to its appropriate marketing strategy. In the early stage, C3 has reached out to different brands and ensured that these brands understand the significance of what C3 attempts to achieve. Although all companies are driving toward sustainability and the ability to offer a waste-based material is a palpable solution, the market barrier persists if companies in this segment fail to pass the right message that answers the right problem in their targeted markets. "*You need to see where your type of product can go and address the question that the market is asking you. You need to approach people with the right answer to their problems so they need to switch their marketing or communication strategy to be able to be more successful if they can offer a good product at lower environmental impacts*" (C3-1).

4.6.5 Case summary

In summary, C3 engaged in searching for sustainable fibres from pineapple leaves, a by-product in the harvesting stage. When these leaves are often burnt or left rotted on the farm, C3's innovation effort contributes to adding value to this waste stream and generating additional income for farmers while solving unsustainable leather production issues in a wide range of industries.

Its engagement is driven by three factors: (1) commitment to upcycling by-products and solving sustainability issues in leather production (2) availability of government funds (3) market preference for upcycled materials. During its engagement process, it encountered three barriers

(1) the technological scale-up challenge with a lengthy R&D period (2) financial hurdles (3) inbound supply chain set-up (4) a lack of market mechanism.

4.7 Chapter summary

This chapter provides a fined-grain analysis at the individual case level with the main objective of reflecting on how the cases perceive their engagement in the food by-product management in the transition towards a circular economy. It is challenging to find and get access to these cases but relentless endeavours resulted in the recruitment of six cases in the UK. Given six cases are purposively chosen to be knowledgeable of the circular economy phenomenon, the perspectives conveyed by each case are considered satisfactory. In general, multiple innovation practices, drivers and barriers emerged from each case providing richer insights into the factors associated with the circular economy movement. In the following chapter, a synopsis of the major findings and patterns which arose from the comparison across cases are presented.

Chapter 5 Cross-case analysis

The findings from within-case analysis (Chapter 4) feed into this chapter, cross-case analysis, to identify the patterns of the data that emerge from comparing and contrasting key findings regarding three research questions that this thesis sets out to explore. This chapter consists of four parts. Section 5.1 depicts the case settings and highlights the overall landscape for food by-product management in the UK. Section 5.2 synthesise the findings to elucidate how six cases adopt the circular practices in terms of procurement, technology, output products and associated markets. In Sections 5.3 and 5.4, the findings from within-case analysis concerning the drivers and barriers perceived by actors across six cases, respectively, are thematically organised into categories and discussed in-depth.

5.1 Case setting

Table 17 synthesises and underscores the various settings of six cases, including the year of establishment, main business main, types of food by-products, and adoption phases. Before getting into further discussion of these settings across cases, it is useful to elaborate on the choice of the cases. As indicated in Section 3.4.1 in the methodology chapter, six cases are purposively sampled for the discovery and selection of information-rich cases associated with the area of interest – the circular economy adoption in the food by-product management. The selected cases are notably experienced with this topic of investigation (Creswell, 2007). Purposive sampling is widely used in qualitative research for its effectiveness in developing a wider picture of the phenomenon. This is opposed to probabilistic or random sampling which is used to assure the generalisability of findings by minimising the potential for bias in selection and controlling for the potential influence of known and unknown confounders. In addition, the cases are purposefully selected based on the maximal variation principles: (1) variation in by-products from different sectors including fruits, vegetables, coffee, and dairy (2) variation in the circular practice adoption phases: laboratory/pilot and commercial scale. Further, the study only involved the companies in the small and medium (SMEs) groups for two reasons. First, the researcher's intention is not to compare and contrast the practices between SMEs and large corporations so the focus on only SMEs facilitates the cross-case analysis. Second, SMEs feature valuable insights from entrepreneurship, which is the key to the circular economy transition in food by-product management. In contrast, large and multinational firms might leave little room for entrepreneurship to emerge.

In the following, six cases are compared in four dimensions (Table 17).

Regarding the years of operations, these cases, except case A1, were newly established from the 2010s onwards. Despite being established in the 1990s, case A1's innovation efforts in garlic valorisation were taken in 2015. This is aligned with the governmental directions where the circular economy has been advocated by the superpower economies – notably embodied by China via the circular economy promotion law in 2008 (The People's Republic of China, 2008) and Europe with the circular economy package in 2014 (European Commission, 2015).

Regarding the main business, the sample cases except for case A1 have the main business that focuses on food by-product valorisations since the starting point. Case A1 is a vegetable processor, not a food by-product recycler; hence, it represents an effort of a vegetable processor that is looking for a diversification of its business lines. This setting partly explains why case A1 eventually abandoned the project and only adopted a decentralised AD technology to convert food wastes to energy instead of other value-added biomaterials. As food by-product management requires a different set of skills, expertise and resources, it is more sensible to separate the valorisation operations from food processing operations. Besides, the cases with the main operation in by-product processing, though voiced some struggles in their operations, continue to go ahead with their innovation pathways and commit to making real changes in the food by-product management landscape in the UK.

Table 17: A synthesis of different case settings

ID	Year	Main business	Sector and stages of by-products in FSC	Innovation phases
A1	1990s	Vegetable processor	Vegetable manufacturing (Garlic by-products)	Lab-scale
A2	2014	Arable food processor	Fruit manufacturing (fruit pomaces)	Lab-scale
A3	2013	By-product processor	Food manufacturing (eggshells)	Pilot scale
C1	2013	By-product processor	Catering (SCGs)	Commercialised
C2	2017	By-product processor	Vegetable manufacturing (potato wastes)	Commercialised
C3	2017	By-product processor	Fruit farming (pineapple leaves)	Commercialised

Source: Created by author

Regarding the sectors and stages in the FSC, six cases cover by-products discharged from different industrial sectors and at different phases of the FSC. Each sector discharges a homogeneous flow of food by-products, which enable the extraction of high-added value products at food and pharmaceutical-grade quality, which is suitable for human consumption and nutrition. Additionally, the selection of by-products from these sectors lines up with the main interests in the extant literature as suggested in the review papers of Mirabella *et al.* (2014) and Caldeira *et al.* (2020). Only cases C1 and C3 handle waste streams discharged from the hospitality and farming stages of the FSC, all remaining cases focus on the food processing sector which is characterised by high homogeneity and segregated sources.

Regarding the innovation phases, A1, A2, and A3 are still at the pilot and lab-scale stages, whereas C1, C2, and C3 have successfully commercialised a part of or entire portfolio of end products in the market. This contributes to enriching the findings as the sampled cases capture various perspectives from the early informants to those who have gone through all stages of the innovation process. In particular, when it comes to the barriers, companies in pilot and lab-scale stages express what they are currently experiencing, whereas those in the commercialisation phase are more likely to reflect on what had happened in the past.

The prevalence of AD is directly linked with the policy direction when the UK government incentivises the energy conversion route. All the UK cases in the sample mentioned no specific government subsidy allocated to the commercialisations of their innovation because the UK landscape prioritises the waste-to-energy route where subsidy is heavily given to the AD plants. This is also consistent with the evidence found in extant literature that the European policy landscape skews toward energy conversion that is located at the near bottom of the food waste hierarchy (see Berbel and Posadillo, 2018).

5.2 Circular practices in food by-product management

This section provides an in-depth examination of similarities and differences across cases concerning RQ1 – *How have circular economy practices been adopted into the management of food by-products?* especially in terms of procurement strategy, technology, end-products and their targeted markets. The key findings are encapsulated in Table 18.

In terms of procurement, except for A1 which uses its own by-product feedstock, all remaining cases are required to set up the inbound supply chain for their operations. This inbound setup is relatively easy for A2, A3 and C2 who source by-products directly or indirectly from a handful of large food manufacturers in the UK where the segregated sources of these waste streams have existed before the involvement of A2, A3 and C2. However, this is a different story for C1 and C3 who need to set up the segregate streams for SCG and pineapple leaves from fragmented locations that had not been done before. In other words, nobody ever acquires SCG and pineapple leaves for industrial production before so these waste streams are not the commodity available in the market to be purchased. C1 and C3 need to organise procurement and logistical collection to ensure the quality and consistency of these feedstocks from hundreds of coffee shops (C1) and hundreds of pineapple cooperatives (C3).

In terms of technology, all six cases have adopted green technological solutions where the indications of lower environmental harm and less energy and resource consumption have been expressed by the informants in six cases. Different technologies have been adopted, and the specific choice depends on the types of feedstock and desirable output products. In A3, an efficient purification process is adopted to produce high-quality calcium carbonate materials from eggshells that fit in the food and pharmaceutical market. In case A1, novel extraction, SFE-CO_2 is experimented with along with the conventional approach, steam distillation, to compare the quality of output products. Subsequently, the residues in these processes are transferred to the onsite AD plant for energy production. Case A2 and C1 both involve novel drying techniques followed by extraction techniques to produce high-value biomaterials. Drying is expressed as the key pre-treatment technology for the success of their operations due to the high moisture levels and quick deterioration nature of these feedstocks. Finally, cases C2 and C3 involve a series of biochemistry processes to convert biowastes into bioplastics and textile materials. Notably, these patent technologies are environmentally sound without the use of toxic chemicals in accordance with its sustainability philosophy.

Table 18: A synthesis of the circular practices adopted by sample cases

ID	Waste types	Research question 1			Circular economy principles		
		Procurement	Technology	Output products with end market	1	2	3
A1	Garlic by-products	N/A	SFE-CO_2, Steam distillation, AD	Garlic oil (Food) Energy (Energy)	x	x	x
A2	Fruit pomace	Direct sourcing at source	Drying followed by micronization, SFE-CO_2	Dietary fibres (Food) Dried seeds for oil extraction (Nutraceutical)	x	x	x
A3	Eggshells	Direct sourcing at source	Purification	Calcium carbonate (Pharma/ Nutraceutical)	x		x
C1	SCGs	Direct sourcing at source	Drying followed by green extraction	Solid fuels (Energy) Biomaterials (Bioplastics) Fragrance (Food)	x	x	x
C2	Potato wastes	Indirect sourcing via a waste collector	Biochemistry	Bioplastics (Fashion)	x		x
C3	Pineapple wastes	Direct sourcing at source	Biochemistry	Vegan leather (Fashion)	x		x

Source: Created by author

Note: Principle 1 refers to the production of high-value creation, principle 2 refers to the cascading biorefinery with multiple output products; principle 3 refers to the use of green technology.

In terms of output products, the end-products cover both raw materials (such as calcium carbonates or bioplastic materials), and final products (such as coffee logs or pallets) that are sold as inputs to other businesses or directly to consumers. In addition, the sample cases are different in the number of end-products to be offered and can be dichotomised into a single output and multiple outputs. In the sample cases, only A1, A2 and C2 aim at multiple outputs to be sold in distinct markets, which fit in the cascading biorefinery model. Specifically, A1, if not abandoned its project, could utilise garlic by-products for oil extraction first before the remaining was fed to the onsite AD plant for energy production. Similarly, A2 dried fruit pomace to produce dietary fibres and dried seeds that are sold for further processing while C2 designed its production process that enables a flexible switch between three product lines, solid fuels, biomaterials and fragrance. By contrast, the remaining cases are limited to a single product line such as calcium carbonate, bioplastic materials and natural fibres that have multiple industrial applications.

In terms of the market for output products, the majority of the end-products are targeted at higher-end markets at the top of the biomass value pyramid, which includes pharmaceutical and nutraceutical markets, fine chemicals, and food. The markets generate higher incomes from the by-product streams, which contributes to circulating resources at their highest utility and value. In addition, these products offer natural-based alternatives for the fossil-based and virgin resources and products, which in turn enables the shift from technical to biological nutrients in the consumable products and reduces the need of tapping into new resources. In addition to these premium markets, solid fuel (coffee logs and pallets from SCG in case C1), though located in the lower range of the biomass value pyramid, still fit in the picture given their high marketable value. Solid fuels offer higher added value compared to energy/biochar in the market. This illuminates why the biomass value pyramid should only be seen as a reference, not a hard and fast rule guiding the conversion pathway.

5.3 Perceived drivers across cases

This section mobilised the drivers that have been mentioned by the informants across six cases to answer RQ2: *Why are firms being driven to be engaged in the circular practices in food by-product management?* First, the patterns of the main driving forces behind the cases' engagement are identified across six cases (Section 5.3.1). Then, all drivers identified by interviewees across cases are then synthesised to generate a list of influencing factors that potentially facilitate the engagement process in the circular economy transition (Section 5.3.2).

5.3.1 Patterns of main drivers across cases

As specified in Chapter 4, the main drivers leading to the engagement of each case vary from case to case. Overall, A1's main driver came directly from the receipt of a government grant in collaboration with some University researchers. For A2, its primary driver derived from its capability with a long drying experience and low capital expenditure. For A3, its significant driver stemmed from its commitment to upcycling eggshells and capital support from the UK government. The remaining cases, C1, C2, C3, share a similar pattern of key engagement driving forces, which include their unwavering commitments to upcycle food by-products, and capital support from the UK government, and a strong market preference for waste-derived materials and products. Since the exploration of the primary driving forces behind the circular economy engagement reveals the pathways and the outcomes of the innovation efforts in each case, it is worthy to look at these driving forces for each case in depth.

Because of being mainly driven by an external force from the government, A1's innovation pathway leaned towards a reactive strategy that mainly relied on the collaboration with external researchers and government funding. As the result, the outcome of this innovation went as far as the external stimulation persisted. As soon as the government funding stopped, the project was abandoned due to a lack of market potential and financial viability, and garlic by-products came back to their original management treatment which is anaerobic digestion.

Since largely driven by its internal capabilities from a long drying experience and low capital expenditure, A2 struggled to go further than these existing capabilities to be genuinely innovative. A2 does not have its own R&D department and hence actively seeks opportunities to collaborate with researchers in prestigious universities in the UK to explore the potential for future expansions. However, as its main competitive advantages rest with drying expertise and low cost, A2 has not been able to tap into higher added value activities such as seed oil extractions for nutraceutical markets. Consequently, A2 has a narrow scope of operations that includes drying pomace to produce natural fibres for the food processing industry and simultaneously exporting seeds for oil extraction companies.

Starting from a strong passion to solve huge problems associated with the underutilisation of eggshells and the recipient of the government funds, A3 chose to engage in R&D to produce premium quality calcium carbonate from eggshells. Thanks to its proactive R&D approach, A3 claimed to be the first company that demonstrates the capability to offer calcium carbonate that meets food and pharmaceutical grades from this abundant waste stream. However, a lack of strong market preference due to the high market entries in the pharmaceutical and nutraceutical sectors, A3 has battled to speed up the commercialisation process. As a result, the outcome of the innovation efforts lies in technological viability whereas economic viability at a suitable scale still needs to be justified.

C1 was primarily driven by a commitment to upcycling SCG, government support and a strong market preference for upcycled products. Sustainability incentivised C1 to take a proactive approach in R&D to create innovative products from SCG. The outcome of this innovation effort is rewarding with multiple product lines offered in the market. Unlike A3, the strong market incentive for acquiring upcycled food enabled C1 to enter the market and make commercial sense of the technology in a short period of time. Interestingly, this strong market trend allowed C1 to position its products, such as coffee logs, in the premium range that can compete effectively in the market in terms of quality, price and carbon footprint.

C2 was largely stimulated by a dedication to simultaneously upcycle food manufacturing wastes and solve plastic problems, government support and a strong market preference for upcycled materials in the fashion industry. With the sustainability and zero-waste philosophy, C2 positioned R&D as its competitive advantage and actively worked with both downstream and upstream partners to solve the sustainability problems. Strong market incentives in the fashion industry for sustainable material alternatives led to a fast growth rate of C2 in this sector. Similar to C1, C2 managed to offer versatile bioplastic materials at a competitive price in the biomaterial market.

C3 was predominantly aroused by a commitment to upcycle pineapple by-products and solve the leather problem, coupled with government support and a strong market preference for an upcycled leather alternative. Established with a sustainability philosophy, C3 actively searched for innovative solutions to add value to a huge volume of agriculture by-products while alleviating some serious sustainability issues in the leather industry. Again, strong market preference in the fashion sector bolsters the success of C3 at an impressive growth rate.

Three crucial patterns can be identified by comparing the patterns of driving forces behind the engagement of six cases.

First, except for A2, all remaining cases were driven by securing capital support from the UK government. In spite of no running grants dedicated to food waste, the possibilities of tapping into generic innovation grants demonstrate a supporting environment for innovations in the UK.

Second, the engagement in the circular economy needs to come from a driven mindset and commitment to retain higher value in food by-products and generate new sustainable materials at the same time. There is a must to have an authentic passion and dedication in the way waste should be considered and transformed into high added-value products. In the first two cases (A1 and A2), this commitment message was vaguely conveyed. Having said that, this does not mean that A1 and A2 disregarded waste issues. Instead, the reasons behind the innovations conducted by A1 and A2 did not emanate from a strong agenda to upcycle wastes, which directly led to a lack of commitment and deep engagement in enduring innovation outcomes. Notably, circular food waste management requires biotechnology investment and systemic change to challenge the way that waste is normally treated. As a result, an unwavering commitment is required for the circular transition.

Third, in order to reap commercial success, the engagement efforts need to be aligned with the market trend. Although A3, C1, C2 and C3 are primarily driven by sustainability, A3 struggles to make a commercial sense of its project due to a high market entry barrier. The signals from pharmaceutical customers to favour upcycled materials, though existed, have been weakly captured by A3. On the other hand, the last three cases quickly justify their commercial viability thanks to their strong market preference for upcycled materials and products. It is interesting to point out that market demands influence innovation efforts. C1 flexibly adapts its three production lines including coffee logs, biomaterials and fragrances in accordance with the dynamic market signals. C2 chose to produce bioplastic materials instead of MDF due to a strong market signal from the fashion market. C3 from the starting point has liaised with the fashion industry where not only sustainability is a primary concern, but consumers are willing to pay a premium price for more sustainable conscious products.

5.3.2 Synthesis of all perceived drivers across cases

Besides these key drivers for the case engagement, six firms also list other influencing factors that facilitate their engagement process. All these factors were coded in the second-order codes, then these codes are refined, relabelled, and aggregated into the first-order code as explained in the cross-case analysis in the Methodology Section (Section 3.4.3.2). A total of 11 drivers (second-order codes) are obtained and grouped into five sources (first-order codes): regulatory, social, managerial cognitive, and economic (Table 19).

Table 19: The list of drivers in the engagement in circular by-product management

Group (First-order codes)	No	Drivers (Second-order codes)	Cases
Regulatory	1	Government grants	A1, A3, C1, C2, C3
	2	Changes in legislation	C1
	3	Regulative aids via networking	A2
	4	Technical supports from WRAP	C1
Social	5	Customer preference for upcycled materials	A3, C1, C2, C3
	6	Consumer preference for local produce	A3
Cognitive	7	Commitment to upcycle food by-products and solve virgin material issues	A3, C1, C2, C3
	8	Motivation to improve CSR	A1
	9	Internal capability with historical experience	A2
Economic	10	Potential economic gains	A1
	11	Low capital investment	A2

Source: Created by author

5.3.2.1 Regulatory drivers

Four drivers are emanating from regulatory sources, including grant schemes, changes in government policy, networking, and technical support. This might be attributable to the fact that the institutional environment of developed countries such as the UK tends to provide good support for biotechnology and innovations.

First, government financial support comes in form of grant schemes for innovation that has created a real boost for all engagements except for A2. These cases received grants associated with the R&D and pilot-scale phases. The fundings come directly or indirectly from Innovate UK, BBSRC, and food waste networks. These fundings contribute to alleviating risks and uncertainty from the early investment decisions and fostering the entrepreneurial mindset of making something different in this field. Interestingly, these findings are linked to the technological development rather than the commercialisation phase, unlike the AD subsidy scheme where subsidy is given to the output produced.

Second, changes in legislation spur the interests of manufacturers in tapping into the food by-product resources. Take the new plastic tax legislation that will take effect from April 2022 (case C1), for example. Under the new law, plastic manufacturers will be charged a tax rate of £200 per tonne of packaging with less than 30% recycled plastic content. This tax will be exempted for those made of 30% recycled plastic or above. The draft legislation has incentivised the plastic manufacturer to look for renewable alternatives, and food by-products emerge as an attractive option because they are not only cheap and abundant but also fit in the recyclable landscape to improve the CSR image of the corporation.

Third, support in form of networking which does not need to be significant in the number has proven to be a bridge linking the innovative by-product processors with their potential customers, as well illustrated in case A2. This also contributes to uplifting the barrier associated with the market entry as the food waste-derived products are often novel and difficult to get into the market.

Finally, technical support has proven to be beneficial in the novel by-product valorisation business. This is an exclusive driver for C1 who established how beneficial organisations such as WRAP are in their development process. WRAP has provided tremendous technical support that contributes to changing the mindset of its suppliers about the food waste hierarchy.

5.3.2.2 Social drivers

In this group of drivers, the cases have identified four trends initiated by the large corporations, consumers as well as end-users that drive the shift towards food by-product valorisation for the recovery of bio-based materials, which include (1) Social preference for the food by-product recycling, (2) Customers' preferences for use of food waste-derived materials and products, (4) End-users' preferences for healthier natural-based materials, (5) Customers' preferences for the locally produced foods and materials.

First, the *consumers' trend favouring upcycled materials* has been captured in A3, C1, C2 and C3. This trend is particularly pronounced in C1, C2 and C3 where the consumers of SCG-derived materials and the fashion industry expressed the willingness to purchase and pay a premium price for more sustainable materials made of these by-products. Not only market entry in these sectors are lower but market demand also facilitates quicker time to market and contributes to alleviating the financial uncertainty associated with the early scale-up phase. On the other hand, this trend is less evident in A3 which operates in pharmaceutical and nutraceutical markets. These markets are conservative and characterised by a prohibitively high market entry, which lengthened the time to market of A3 and caused financial difficulties for A3 to scale up the technological process. A3 is therefore still looking for commitments from potential buyers – giant pharmaceutical corporations. This preference has been mentioned in the literature. For instance, a recognition of a clear trend in the industry toward the efficient, inexpensive, and environmentally friendly processing of food wastes and agro-industrial by-products for recovery of high-value substances, which might find various applications, e.g. as food-grade ingredients, food additives, nutraceuticals and other products, which is consistent with Galanakis (2012).

Second, consumers' preference for local produce was emphasised in the case of eggshell (A3) as a driving force for its innovative effort. The FSCs have become increasingly complicated due to their global presence. In the UK, calcium carbonates are vastly mined in China and exported to the UK. Hence, the utilisations of the locally produced by-products in these cases offer the solution for the development of a more resilient FSC by reducing the risk and pressure from heavy import reliance. This trend becomes more evident as a result of the COVID-19 but it is not strong enough to remove the market barrier in the pharmaceutical market for case A3.

5.3.2.3 Managerial cognitive drivers

In this group, three drivers are retrieved from the findings in six cases, which include a top managerial commitment to upcycling food by-products and solving sustainability problems, internal capability thanks to long experience, and motivation to improve SCR.

First, *commitment to upcycling food waste* is underlined as the crucial driver moving them forward as explained above. This commitment links to the awareness of underutilisation issues associated with the prevailing treatments of food by-products in the UK. While food by-products are homogeneous and rich in nutrients and bioactive compounds, their full potential has not been recognised. The descriptions of the prominent treatments of these resources in each case well illustrate this driver and contribute to elucidating why the cases want to make a difference and challenge the status quo of the prevailing food waste management in the UK. Driven by a sustainability-driven mindset, A3, C1, C2 and C3 commit to demonstrating that these by-products can be valorised in an eco-friendly manner while generating a spectrum of HVAP that add more value to the by-products from FSC. By tapping into the by-products that would otherwise go wasted, these sustainability-driven firms are actively looking for novel solutions to solve simultaneously the food waste management issues and virgin resource depletion problem.

Second, leveraging existing capability is an exclusive driver for A2. A2 has a century's history of farming with decades of experience in drying arable foods. This is the source of inspiration for its owners to overcome the challenges associated with collecting and processing food by-products as well as marketing their end-products. The knowledge and expertise in food drying technology allow the smooth transfer to similar environments.

Third, the CSR enhancement is mentioned as an exclusive driver in case A1 as the result of its background as a vegetable processor rather than a by-product processor. If A1 successfully valorised garlic oil from garlic residues at a cost-effective scale, it would be a huge boost to its corporate social responsibility and sustainability image. Unlike A1, the remaining companies established with sustainability integrated into their DNA, hence their CSR has been well-positioned at the starting point. Take C3, for instance. It has continuously strived to lower its carbon footprint and reflected its sustainability philosophy. "*We look close to the production line to see where has the big impact, and we run LCA of the supply chain and work on how we can improve. We managed to improve the CO2 emission of our supply chain by 40% in one year. We run the second this year and continue working on that. The next year we will run the third one*" (C3-3). Therefore, CSR enhancement has not been mentioned in other cases.

5.3.2.4 Economic drivers

The economic drivers for the circular engagement are expressed in cases A2

First, low capital investment is an exclusive driver for case A2. Thanks to many years of experience in drying arable businesses, A2 is in the position to acquire and reconfigure the second-hand machinery in other industries to serve their purposes at low capital investment. This driver is intrinsically linked to the internal capability driver mentioned earlier.

Second, the potential economic gains from the successful adoption are cited as a driver for the engagement of case A1. Of note, although all cases acknowledge the potential revenue gained from better utilisation of the resources, the economic gains are not cited as a clear driver for their engagement in the first place due to the challenges associated with and risk involved in the technological development.

5.4 Perceived barriers across cases

This section summarised the barriers derived from the findings across six cases (Table 20**Error! Reference source not found.**) to answer RQ3: *Why does their engagement in the circular practices in the food by-product management being derailed or hindered?*

Unlike drivers, interviewees across six cases did not reveal the relative importance of barriers to their operations for two reasons. First, barriers might occur at different points of engagement, so it is not possible to reflect and give them a meaningful ranking. Second, these barriers often intertwine with each other. For instance, technological scale-up challenges with a long R&D and financial constraints often go hand in hand. Thus, interviewees argued that the acknowledgement of all barriers in retrospect from their experience is beneficial to the practitioners who consider participating in this bumpy road of the circular transition. A list of 13 barriers (second-order codes) was retrieved and arranged into six sources (first-order codes), which consist of regulatory, social, managerial cognitive, technological, economic and market, as well as supply chain barriers.

Table 20: The list of barriers to the engagement in circular by-product management

Group (First-order codes)	No	Barriers (Second-order codes)	Cases
Regulatory	1	Bureaucratic end of life legislation	C1
	2	Costly standardisations for end products	C1
	3	Policy shaping AD as default landscape	C1
Social	4	Wrong waste mindset	A3
	5	Over-reliance on the waste hierarchy	C1
Cognitive	6	Psychological fear	A1, C2
Economic	7	Financial challenges	A1, A3, C2, C3
	8	A lack of a market mechanism	A1, A2, A3, C1
	9	High market entry	A3, C1
Technological	10	Technological scale-up challenges with lengthy R&D	A1, A3, C1, C2, C3
	11	Resource incompatibility	A1
Supply chain	12	Sourcing risk due to seasonality and short contract length	A2
	13	Intricate inbound logistics set up due to no aggregated waste streams	C1, C3

Source: Created by author

5.4.1 Regulative barriers

Policy and legislation can be instrumental in the circular engagement, but they can also pose serious challenges to the circular innovations as mentioned in the sample cases. Regulatory barriers can be in the form of bureaucratic procedures for the commercialisation of food waste-derived products, costly standardisation processes, and the overall policy landscape. Interesting, these three barriers are exclusive barriers revealed by C1.

First, the bureaucratic procedure for the commercialisation of food waste-derived products is overly underlined by C1 which entered the commercialisation phase. Owning to selling the products made of what considers waste, C1 has to go through all sorts of procedures to be able to demonstrate the safety of the final products. These legislations are time-consuming and add high burdens to the innovation efforts.

Second, the costly standardisation process derived from the eco-design standard and safe-to-burn rating legislation on solid fuel products. The extravagant costs of testing and getting solid fuels certified cannot be absorbed by a start-up like case C1. This represents another barrier to hindering the process of launching its products to the market.

Third, the overall institutional landscape could potentially hinder the sourcing security of C1. The UK policy gives priority to energy conversion through AD, which could cause a competition of SCG feedstocks between AD plants and case C1. Although SCG does not work effectively in the AD plants, AD operators still acquire SCG in times of lacking feedstock, such as during the COVID-19 period when catering outlets are forced to close.

5.4.2 Social barriers

In this group, the barriers consist of two factors: the wrong waste mindset and the over-reliance on waste hierarchy.

First, the mindset of treating by-products as waste hinders the upcycling of this valuable resource. Food processors mainly focus their attention on the core business, which is to process and generate higher value from main products. By-products are treated as waste along with wastewater and packaging wastes by handing them over to third parties, such as waste recycling companies or AD plants. As long as by-product treatment does not incur significant costs of handling, by-product processors are satisfied with their revenue portfolio. The sampled cases have pointed out two issues associated with this mindset. First, by-products once classified as wastes are not handled with care, which impairs the quality for further processing into HVAP. Second, the word 'waste' incurs the feeling of cheapness and hesitation in the consumption stage. For the by-products to be utilised to their fullest potential, A3 called for a change in the terminology where food waste or by-products should be referred to as *co-product* instead.

Second, the industrial reliance on waste hierarchy limits the options for innovative products. Take the case of solid fuel, for instance. The current waste hierarchy favours AD over fuel production, despite the fact that the coffee logs are identified as a premium household product that adds much higher value compared to the AD food-to-energy option. Because of the assumption that solid fuel production is not as environmentally friendly as AD according to the waste hierarchy, processors were reluctant to give the SCG feedstocks to case C1, forcing C1 to conduct the life cycle assessment to demonstrate its carbon footprint saving in comparison to the AD.

5.4.3 Managerial cognitive barrier

In this group, the low interest of processors in by-product valorisation due to psychological fear is identified as the managerial barrier. A1 as a food processor justified the low interest among food processors in the food by-product valorisations. This is because of a psychological fear when moving from a simple food environment to an environment that entails technological advances with the fear of unknown factors. This is also supported in C2 which mentioned that the majority of the bioplastic manufacturers prefer working with nice, clean and consistent virgin materials instead of messy waste streams due to the psychological barriers.

5.4.4 Economic and market barriers

This group is boldly stated as the key hindrances to the food by-product valorisation efforts under the circular economy context.

First, huge capital investment and long payback are financial issues associated with biotechnology development. According to case A3, raising capital for food by-product valorisation represents a huge challenge due to the risk appetite of the bank. Further, the novel waste-derived products often take a longer time to enter the market in order to start generating income, which further impairs the positive cash flow and extends the payback periods of the investment.

Second, a lack of market mechanism poses a substantial challenge for food by-product valorisation. In the production process that involves virgin materials with hundreds of years of experience and expertise, producers can plan the markets where their outputs are sold, as well as reliably estimate the economic outcomes of the investment. By contrast, in the novel food by-product valorisation process, until practically getting the products out of food by-products, nobody is certain of the outcomes such as the quality, nutrition value and marketable prices of the outputs. Whether the output fits in the pharmaceutical or food or feed industry depends largely on the quality of the feedstock, technological choices, operational aspects, as well as supply-demand dynamics.

Third, market entry has been cited as a big issue for the higher-end markets, particularly the pharmaceutical industry or the sector characterised by monology. Despite huge rewards, the pharmaceutical sector is conservative and hard to get into. As such, any cases that supply pharmaceutical-grade products express this prohibitively high market entry as the key barrier to be uplifted.

5.4.5 Technological barriers

The sampled cases have demonstrated that the technological development for food by-product valorisation is a bumpy road that encounters (1) the technological scale-up challenges, and (2) compatibility with the internal capability.

First, technology scale-up has been highlighted to be a real problem in by-product valorisation. The success at the laboratory and pilot-scale cannot guarantee the same success that can be reaped in the commercialisation phase. To achieve commercial success, it is important to find the technology supplier at the desirable scale that renders cost-effectiveness and quality assurance. However, this can be a daunting task. This barrier is the key reason for case A1 to abandon its project. This barrier no longer existed once the cases entered the commercialisation phase. Interestingly, the barrier is now seen as the competitive advantage of these cases, which hinders competitors to enter their segments, and some cases such as case C1 boldly stated that they do not expect to see any competitors soon because of the complicated technical know-how.

Second, the choice of technology that is compatible with the internal resource is signified as a barrier for case A1, which prevented case A1 from going further in its innovation path. The choice of technology greatly depends on the capability of the processors in terms of labour, capital resources, and existing know-how.

5.4.6 Supply chain barriers

The factors stemming from sourcing and supply chain are identified as significant challenges for the food by-product valorisations. There are two factors named in our cases: seasonality and a lack of segregated waste stream.

First, seasonality and short-contract length are presented as the main operational barrier for case A2. Although case A2 has considered some strategies to alleviate the seasonality risks, including using multiple feedstocks and sourcing from other countries, case A2 still struggles at the moment with this issue.

Second, an exclusive barrier for C1 and C3 is that there is no segregated waste stream that existed for the material collection and acquisitions. Unlike other cases using materials from manufacturing stages characterised by large quantities at a few locations, C1 and C3 are the only cases that take feedstocks from farming and hospitality stages. C3 struggled to establish a supply chain to acquire and collect pineapple leaves that had never been sold before while C1 encountered challenges from the collection of SCG from a dispersed network of hundred small coffee shops. Additionally, SCG is often found to be mixed with other waste streams in coffee shops, causing a real challenge for C1 to organise a homogeneous and segregated stream of feedstock.

5.5 Chapter summary

The section provided a cross-case analysis of the adoption of the circular economy in food by-product management within six cases. Major findings associated with three research questions are compared and debated. To ensure research quality with respect to transparency, reliability and validity, the chapter that follows will compare and discuss the key findings found in these cases with extant literature to derive possible generalisations or assertions.

Chapter 6 Discussions and juxtaposition to theory

In the previous Chapters (Chapter 4 and Chapter 5), the findings on the circular practices and associated determinants derived from the raw data have been presented. This chapter will espouse the relationships between these emergent findings with extant literature and with the constructs specified in the institutional theory to derive additional insights and contribute to theoretical refinement. This chapter is divided into two parts. The first section (Section 6.1) discusses the streams of discussion that correspond with three research questions addressed in this study in order to enhance consistency and clarity. The second section, Section 6.2, offers a reflection of the findings from the theoretical anchor of the institutional theory. From here, a unified framework with three prepositions is proposed and discussed to establish the relationship between empirical drivers, barriers and practices found in this thesis.

6.1 Comparison of the findings with extant literature

6.1.1 Comparison of circular practices with extant literature

RQ1 sets out to identify the circular practices adopted in firms operating in food by-product management. The evidence in six cases shows how three intrinsic principles – higher value creation, cascading biorefinery, and green technology – are operationalised. To the best knowledge of the researcher, this is the first attempt to interpret and translate the overarching concept of the circular economy into the management of food by-products. As demonstrated in Table 18, only two principles, higher value creation using green technology, are explicitly espoused across six cases, whereas the evidence of cascading biorefinery is shown in A1, A2 and C1. There are two explanations for this. First, cascading biorefinery principle might be inapplicable to certain types of by-products such as potato peels when they can only be utilised to produce one type of materials. In the cases where cascading is not applicable, evidence of recovering these materials in their highest quality and value using green technologies is ascertained. Second, some cases have not utilised the materials in the by-products to their fullest extent, which leads to a partially completed innovation. Specifically, eggshells consist of two crucial parts, eggshells and membrane, but A3 only recovers calcium carbonate from eggshells while the membrane is currently wasted. Undoubtedly, all efforts captured in the sampled cases should be hailed in the progress of shifting from a linear and recycling economy to a circular one. However, in order to induce and smoothen a complete transition, I argue that all three principles in the circular economy should be articulated to the practitioners, policymakers and academia alike. Furthermore, these principles and waste hierarchy are not mutually exclusive, but these principles play a complementary role to overcome the rigidness of the conventional waste hierarchy. Again, I underscore the unique contribution of specifying three explicit principles to the extant body of literature on circular food by-product management.

Next, the comparison of the finding with respect to technology, output products and their markets with the evidence found in the literature is discussed.

In terms of technology, some technological choices such as those taken by A1, A2, A3, and C2 are aligned with the popular pathway discussed in the literature, whereas those taken by C1 and C3 add novelties to the literature. For example, the purification process proposed in A3 is presented as a novel approach that has not been discussed in the literature to retrieve high-quality calcium carbonates at pharmaceutical and food grades. In the cases of A1 and A2, novel green extraction SFE-CO_2 is widely discussed in the literature, such as in Ekinci and Gürü (2014); Barrales *et al.* (2015). Although these papers examined the potential use and benefits of SFE-CO_2 on different types of fruit by-products, practical evidence found in this thesis substantiates the prospects of this technology in valorising by-products from the fruits and vegetable processing sector. Similarly in C2, the production of biodegradable plastics made of potato wastes has been widely discussed in the literature. On the other hand, C1 and C3 offer novel technological choices that have not been discussed in the extant literature and therefore add more nuances to existing literature. Further, this study argues that as long as the circular economy principles are articulated, the by-product processors should be flexible and entrepreneurial in the choice of conversion pathways that suit their internal resources and capabilities.

In terms of output products, all cases aim at the production of high-value materials and products which are consistent with the biomass value pyramid that has been dominant in the academic discourse (Berbel and Posadillo, 2018). These products include fine chemicals and supplements, food ingredients, and biomaterials. In the cascading approach, a spectrum of products is generated. For instance, C1 offers coffee logs, fragrance extracts and biomaterials from SCGs. The generation of these products from food residues fits well with the mainstream discussions in literature (see Mirabella *et al.*, 2014; Dahiya *et al.*, 2018). Unlike the common norms of food by-product recycling in the UK that aims at energy, feed production and landfill, the sampled cases espouse practices that seek to maximise the efficiency of biomass use and thereby contribute to wealth generation. When literature claims that food waste-based projects at an industrial scale are rare (Santagata *et al.*, 2021), the successful cases at the commercial stage fill in this void.

In terms of the market, these products aim to be sold in the pharmaceutical, nutraceutical, food and fashion industries. An exception is solid fuels (coffee logs and pallets), which are sold in the energy market, but this product is positioned in a high-end market and can replace the wood logs for household and commercial use. Again, this finding provides an insightful nuance to the literature that circular by-product management should be flexible and justified on a case-to-case basis.

6.1.2 Comparison of perceived drivers and barriers with extant literature

RQ2 and RQ3 enable the identification of 11 drivers and 13 barriers in comparison with extant literature. Some findings are consistent with and reinforce available evidence in the literature, while others reflect new and important revelations. Table 21 and Table 22 underline which factors are consistent with the findings in the literature, and which ones are exclusive to this study.

6.1.2.1 Discussion of perceived drivers

The findings indicate a list of 11 drivers that emerge from four themes: (1) regulatory, (2) social (3) cognitive (4) economic (Table 21). The comparison between findings in this study and evidence found in the literature on each theme will be provided next. The finding in this case with supplementary case context and interview quotations reinforce the roles of laws and regulations in driving the circular transition in the food sector. The stories behind each driver across six cases elucidate its abstract name.

Among the four drivers of the regulatory theme, two similar to those discussed in the literature are government grants and changes in legislation. This supports the instrumental role of policymakers in the overall circular economy transition. Interesting, C1 provides how the change in plastic law drives the interest in the valorisations of by-products to produce biomaterials, which has not been discussed in prior literature. Two exclusive findings found in this theme consist of government support in terms of networking and technical support from the government. Besides fiscal support, networking and technical support are underscored in generating opportunities for novel food by-product businesses.

Both drivers of the social theme have been discussed in the literature, which includes the market preferences of end-users and corporate customers for upcycling food by-products and social preference for local produce.

Among three drivers of the cognitive theme, only commitment to upcycling food by-products and solving sustainability problems have been mentioned in the literature. Motivation to improve CSR and internal capability history background are newly found in this thesis. This further strengthens the determining role of managerial perceptions and dedication to the circular economy transition.

Among the two drivers of economic theme, the potential economic gain is also found as a driver in literature. The findings in this study further illustrated that economic gain can be achieved from higher revenue generation and cost-saving thanks to less waste stream. One exclusive driver in this category comes from low capital investment in case A2. This case has acquired and reconfigured the second-hand machinery to fit its purpose.

In total, the study found six drivers that are consistent with the one in the literature and five exclusive drivers that add diversity to the current knowledge. Interestingly, none of the cases mentions technological factors as a driver for their engagement, which is somewhat contradictory to the argument found in the literature. The rationale for this is that although green technologies exist as claimed by Sheppard *et al.* (2020), their application in treating food by-products exhibits inconsistency in terms of process yields and overall quality, which not only adds complexity but also high uncertainty to the investment. As a consequence, the sampled cases are often driven by factors from other sources to engage in technological development rather than the technology itself.

Table 21: Comparison of the driving factors with extant literature

Themes	**No**	**Drivers**	**Compared with extant literature**
Regulatory	1	Government grants	Ong *et al.* (2018); Boumali *et al.* (2020).
	2	Changes in legislation	Gregg *et al.* (2020)
	3	Regulative aids via networking	Exclusive factor
	4	Technical supports	Exclusive factor
Social	5	Customer preference for upcycled materials	Joshi and Visvanathan (2019); Santagata *et al.* (2021)
	6	Consumer preference for local produce	Gregg *et al.* (2020); Donner *et al.* (2021)
Cognitive	7	Commitment to upcycle food by-products and solve sustainability issues	(Joshi and Visvanathan, 2019; Leder et al., 2020)
	8	Motivation to improve CSR	Exclusive factor
	9	Internal capability with historical experience	Exclusive factor
Economic	10	Potential economic gains	Sheppard *et al.* (2020); Donner *et al.* (2021)
	11	Low capital investment	Exclusive factor

Source: Created by author

6.1.2.2 Discussion of perceived barriers

With respect to barriers, 13 barriers from six themes are found across the sampled cases (Table 22). Again, a detailed comparison between this study's findings and evidence found in literature in each theme will be provided next.

Among three barriers in the regulatory themes, bureaucratic end-of-life legislation and overall landscape prioritising AD are consistent with the findings in the extant literature. Sadhukhan *et al.* (2020) criticised how fiscal incentives (such as Feed-in-Tariff, Renewable Heat Incentive, and Renewable Transport Fuel Obligation) are available but are designed to support only energy conversion – located at the bottom of the biomass hierarchy pyramid. One novel barrier to be added to literature is costly standardisation for end-products. This financial burden is an interesting aspect because the literature mainly points to the bureaucratic challenges of laws and legislation.

Two barriers found in the social theme, which include a wrong industrial waste mindset and over-reliance on the waste hierarchy, are exclusively found in this study. To stimulate interest in the by-product valorisation, it is crucial to alter this mindset and treat the by-products as co-products in the processing factories. The same is applied to the reliance on the waste hierarchy. Instead of referring to the waste hierarchy as a guideline, industrial stakeholders become heavily dependent on its ranking and sceptical of any innovations that might go against it.

The only cognitive barrier derives from psychological fear that has been debated in extant literature. This fear has caused the low interest of stakeholders in FSC to invest in the by-products valorisation (Boumali *et al.*, 2020; Leder *et al.*, 2020),

All three barriers in the economic theme identified in this study reflect the findings in the literature, which include financial hurdles, a lack of market mechanism, and prohibitively high market entry. A lack of market mechanism is accentuated by a high number of cases because, at the time of engagement, these cases are not certain of what types and quality of end-products can be recovered to determine a clear market route for them. The study further specifies that high market entry is more pertinent to the end products that go to the pharmaceutical/nutraceutical market as well as the market characterised by monology.

Similarly, two barriers in the technological theme appear in extant literature discussion. Technological upscaling challenges and incompatibility of the technology with existing resources create enormous challenges and uncertainty for the companies to engage in the technological development for by-product management. The central argument put forward by the interviewees is that it is challenging to develop a technological option at a suitable scale that can achieve cost-effectiveness while generating outputs at a desirable quality.

Among two barriers in the supply chain theme, only sourcing risk due to seasonality and short contract length is cited in the literature. Logistical challenges were a unique barrier mentioned in cases C1 and C3 due to the nature of waste feedstocks discharged at farming and hospitality stages that require them to be collected at dispersed locations in small quantities.

Table 22: Comparison of the hindering factors with the extant literature

Themes	No	Barriers	Comparison with extant literature
Regulatory	1	Bureaucratic end-of-life legislation	Boumali *et al.* (2020); Leder *et al.* (2020); Donner *et al.* (2021)
	2	Costly standardisations for end products	Exclusive barrier
	3	Regulations supporting AD as the default landscape	Sadhukhan *et al.* (2020)
Social	4	Wrong waste mindsets among stakeholders	Exclusive barrier
	5	Over-reliance on the waste hierarchy	Exclusive barrier
Cognitive	6	Psychological fear in the engagement in the novel circular practices	Boumali *et al.* (2020); Leder *et al.* (2020)
Economic and finance	7	Financial challenges	Gregg *et al.* (2020)
	8	A lack of a market mechanism	Boumali *et al.* (2020); Gregg *et al.* (2020)
	9	Prohibitively high market entry	Donner *et al.* (2021)
Technology	10	Technological scale-up challenges	Boumali *et al.* (2020); Nawaz *et al.* (2020); Donner *et al.* (2021)
	11	Resource incompatibility	Boumali *et al.* (2020); Leder *et al.* (2020)
Supply chain	12	Sourcing risk due to seasonality and short contract length	Pal and Suresh (2016); Joshi and Visvanathan (2019); Donner *et al.* (2021)
	13	Logistical complexity due to no aggregated waste streams	Exclusive barrier

Source: Created by author

6.1.3 Summary of the comparison with extant literature

In general, the circular practices adopted by the cases are consistent with the technological pathways, portfolio of output products, and market for these products as suggested by academic literature. For eggshell, a dairy by-product, calcium carbonate is recovered utilising the purification process to retrieve food and pharmaceutical grade end products. For by-products from the fruit and vegetable processing sector, dietary fibres and seed oils are retrieved to return to the human food chain using green extraction techniques. Similarly, the conversion of potato peels into plastics using a biochemical process has been found. Further, the evidence of technological choices in C1 and C3 adds more nuance to the existing literature as the technological pathways adopted by these cases have not been discussed in earlier literature.

With respect to the drivers and barriers to these adoptions, six drivers and nine barriers are aligned with those found in the literature, thereby reinforcing the literature with rich empirical evidence. Besides, some exclusive factors that emerge from the novel findings of the cases contribute to advancing the knowledge in this nascent field. In the next section, the findings of this study will be juxtaposed with the critical constructs of the institutional theory in order to derive theoretical contributions.

6.2 An integrated framework for a circular food by-product management

This section elaborates on the findings unearthed in the sample cases and the theoretical lens of the institutional theory. First, section 6.2.1 establishes the logic for the circular food by-product management from the interpretations of the stakeholders' perceptions in six cases. Second, section 6.2.2 synthesises the drivers and barriers hindering the shift in institutional logic from the integrated institutional theory perspective. Lastly, an analytical framework (Section 6.2.3) with three prepositions will be discussed.

6.2.1 Institutional logic in the circular food by-product management

6.2.1.1 Institutional logic of the circular economy

This section specifies the institutional logic of the circular economy emerging from the interpretations of the findings across six cases and ascertains the dominant logic that interviewees perceive in the UK environment.

There was sufficient evidence that circular practices enable sample cases to achieve the dual objectives of economic value and environmental goals, this thesis establishes the circular economy logic as a legitimacy-embedded efficiency. The dual attainment of economic and environmental value is also consistent with the argument put forward by literature in this area. Economic value is retained by lowering operational costs and preventing compound degradation in the waste over time (Morone *et al.*, 2019), while environmental goals are achieved by not only the use of greener technologies eliminating the use of potential polluted chemicals but also by generating less downstream waste through higher resource utilisation. Moreover, many output products offer an answer to tackle the issues of resource scarcity, plastic and fashion issues. This ensures the attainment of diet sustainability by obtaining end products intended for human nutrition. These benefits have been discussed in the circular economy literature in general (Venkata Mohan *et al.*, 2019) and food by-product valorisation in particular (Lucarini *et al.*, 2020). Our findings further strengthen the claim that the circular economy is a workable socio-techno regime that decouples resource growth from resource depletion and environmental harm (Ghisellini *et al.*, 2016; Murray *et al.*, 2017; Merli *et al.*, 2018) and the legitimacy-efficiency logic of the circular economy offer a shared understanding for all stakeholders, including practitioners, policymakers and academia to bond and achieve this goal. When no clear 'isomorphism' pattern was observed in the circular practice across these cases, the introduction of the institutional logic offers the unique feature that bonds these disparate patterns in the circular paradigm.

The thematic analysis of the findings reveals 'low efficiency' as the dominant logic perceived by the interviewees in food by-product management in the overall landscape of the UK. As boldly expressed by the interviewees, the UK institutional landscape favours the waste-to-energy pathway, particularly AD. As explicitly discussed in Section 4, this option is located near the bottom of the food waste hierarchy because AD, though contributes to returning nutrients to soil while generating renewable energy, does not retain materials at their highest utility and value. As such, this study interpreted that *low efficiency* is the prevailing logic for generic food by-product management in the UK context. I, therefore, posits that the UK is at its infant stage of transitioning from the institutional logic of low-efficiency to a legitimacy-embedded efficiency logic during the circular economy transition. The cases under this investigation signify the endeavours to trigger and facilitate the transition in the prevailing logic.

6.2.1.2 Difference between the institutional logics of the circular economy and sustainability

The incorporation of the institutional logic in this study offers a unique contribution to distinguishing the circular economy from the sustainability paradigm. By comparing the findings in this study with those in sustainable supply chain management (SSCM) studies, this study highlights a fundamental difference in the institutional logic arising from the two concepts.

In SSCM, legitimacy and efficiency logics are perceived as contradictory, with the former being dominant. The adoption of green practices represents a desire to enhance 'legitimacy' in lieu of cost-saving. The findings of Glover *et al.,* (2014) on the UK milk supply chain, for instance, indicated that environmentally friendly practices are frequently linked to huge initial investment costs with little immediate financial rewards, contradicting the logic of cost reduction in business. As a result, the sustainability agenda in milk farms are primarily driven by retailer pressure—dominant players who, in turn, find themselves under the legitimate pressure of the government and society. To sustain environmentally friendly practices, there is a call for an increased role of governments and for collaboration among stakeholders in aligning the conflicting logics of profit maximisation and sustainability investment (Glover *et al.,* 2014). Institutionalists suggest that, should misalignment persist, symbolic compliance or 'decoupling' strategies will emerge and jeopardise the authentic diffusion of the practice (Thornton and Ocasio, 2008).

The circular economy, on the other hand, is intrinsically an economic concept; so, cost-reduction and/or profit maximisation are viewed as the main goal (Liu *et al.*, 2018). The circular economy's ideology, at the same time, extends to embracing the sustainability agenda. The circular economy is therefore described in more precise terms as an attempt to integrate "*economic activity with environmental well-being in a sustainable way*" (Murray *et al.*, 2017, p. 369). The circular economy offers a workable socio-technical regime suited to achieve economic and ecological sustainability, which makes it compatible with the urgent need of businesses and countries to reduce input costs, as well as with their desire to operate in a less unpredictable world (World Economic Forum, 2014). Speaking in the language of institutionalists, the socio-technical regime bestowed by the circular economy enables the reconciliation of the two conflicting logics of 'efficiency' and 'sustainability'. The more efficiently are raw material resources used, the more profitability firms attain and, at the same time, the more sustainable the economy becomes.

The analysis asserts that institutional logic highlights the fundamental differences between circular economy studies and green SCM research. While green SCM is aimed at enhancing firm legitimacy at the expense of efficiency, the circular economy offers a good balance between the two. This also justifies why the purely sociological stream of research has become popular in green SCM studies (Liu *et al.*, 2018). As we position circular economy as a *legitimacy-embedded efficiency* paradigm, it, therefore, allows the integration of the sociological and economic variants of institutional theory.

6.2.2 Institutional pressures in the circular food by-product management

In the language of the institutionalists, the circular practices adopted in the sample cases represent the legitimacy-embedded efficiency logic. Whether this logic can be dominant and gradually replaces the existing logic of low efficiency and possible unsustainability as analysed above depends greatly on the institutional pressures which arise from sociological and economic variants of the institutional theory. Sayed *et al.* (2017) claimed the interconnection between the institutional pressure and the institutional logic where the institutional pressure can drive and impede the shift in the dominant logic. In this study, the drivers and barriers identified in the cases represent the institutional pressures, and the findings of the study confirm the influence of these factors on the shift in the dominant logic.

Despite the provisional nature of the drivers and barriers identified in this study, they have been rooted in six themes, which include regulatory, social, cognitive, economic, supply chain, and technological themes. Applying the integrated institutional theory, the first three themes represent the legitimacy-seeking pressure corresponding to the sociological variant of the institutional theory, while the last three themes are associated with the efficiency-seeking pressure corresponding to the economic variant of the institutional theory. Specifically, as discussed in the literature chapter, the sociological variant provided three mechanisms for legitimacy-seeking: *(i) coercive pressure*, which derives from law and regulation factors; *(ii) normative pressure*, which stems from social norms and cultural factors; and *(iii) mimetic pressure*, which arises from the cognitive factor to copy the actions of other firms to reduce uncertainty. The economic variant supplements three mechanisms: (i) frequency-based imitation, which refers to the mimicking of those actions that reach a critical mass of adopters (Zucker, 1987); (ii) trait-based imitation, which involves the adoption of those practices espoused by prestigious firms; and (iii) outcome-based imitation, which entails copying those actions providing salient positive outcomes (Haunschild and Miner, 1997). The frequency and trait-based forms of imitation are attributed to technological factors, whereas outcome-based imitation leans towards economic and supply chain factors. Taken together, the extended institutional theory gives rise to five distinct sources of pressure: (i) regulatory, (ii) social (iii) cognitive, (iv) economic, and (v) technological (Figure 13). Whereas the first three groups aim at enhancing the legitimacy of the adopted practice, the last two groups contribute to improving its efficiency.

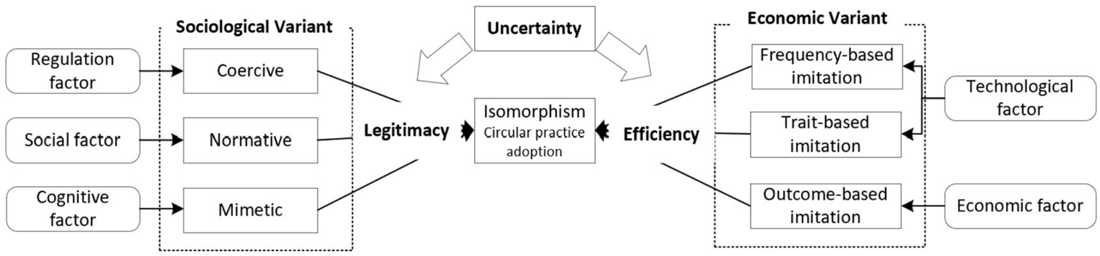


Figure 13: A theory-based classification of the influencing factors on the circular economy transition

Source: Created by author

Compared to the classification approach proposed in literature such as in Kirchherr *et al.* (2018), Tura *et al.* (2019) or Russell *et al.* (2020), this novel theory-based taxonomy that dichotomises six themes into the legitimacy and efficiency groups offers a unique advantage. It contributes to answering the question of which factors wield more or less influence on the circular economy transition. According to Kauppi (2013), when experiencing deep uncertainty from either market demand or technological feasibility, firms are less likely to adopt a practice by efficiency pressure, but more by legitimacy force. In other words, regulatory, social and cognitive factors (legitimacy group) have a stronger influence than economic/supply chain and technological factors (efficiency group) in the presence of certainty. As such, the perceived uncertainty acts as a moderator, shifting the influence between legitimacy and efficiency pressure in the adoption of a circular practice.

Reflecting on the findings of the sample cases, high uncertainty is overwhelmingly perceived at the time of investing in the circular food by-product valorisations, which is strengthened by a variety of barriers perceived from market and technological sources found in each case. In this condition, the findings regarding the list of drivers validate the argument that firms are more likely to be driven by regulatory, social and cognitive sources.

6.2.3 Analytical framework

This section aims to propose and discuss a coherent analytical framework that brings together all the aspects that this study sets out to explore: circular economy practices and associated drivers and barriers (Figure 14). The contributions of the framework will be discussed next in order to lead to three prepositions that enlarge the prior knowledge of institutional theory.

First, this study sheds light on the relationship between institutional logic and institutional influencers. Institutional logic corresponds to the nature of the practices adopted in the same cases. Institutional influencers, also called institutional pressures, represent the drivers and barriers that affect the process of making these logics dominant in the organisational field, which is the food by-product processing field in this study. Literature has claimed that the shift in dominant institutional logic is the result of the institutional pressures that contribute to fortifying one logic over another or creating a new logic (Thornton and Ocasio, 1999; Reay and Hinings, 2009). The findings further add how institutional pressure can speed up or slow down the shift in dominant logic. Further, Table 22 indicates that the perception of barriers, such as wrong waste mindset or regulation favouring AD, may be influenced by the prevailing logic (low-efficiency logic) in the market. This leads to the following proposition:

P1: Institutional pressures can facilitate and hinder the shift in dominant institutional logic. Since the circular economy aims at dual goals of economic and environmental achievements, both legitimacy and efficiency pressures play a role in that shift towards the circular economy. Circular economy logic is established as legitimacy-embedded efficiency.

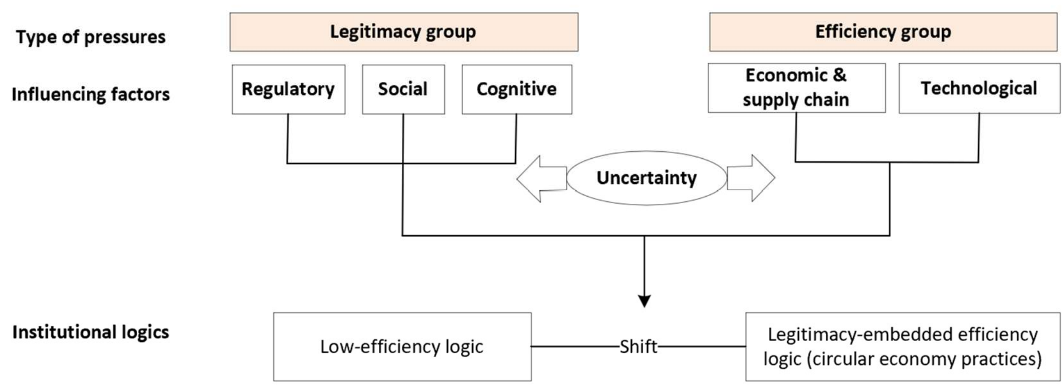


Figure 14: The circular economy paradigm from extended institutional theory

Source: Created by author

Second, this study supplements empirical evidence into the extant literature regarding deep uncertainty represented by the economic/supply chain and financial factors (Table 22). In that condition, the shift in logic is initiated mainly by the legitimacy factors. As analysed in Section 5.3.1 on the patterns of main drivers behind the engagement of six cases, firms need to be driven by an unwavering cognitive driver to make authentic impacts. Regulatory pressure alone (as in A1) is not sufficient to guarantee the circular transition, and firms such as A1 tend to be reactive in responding to the government's actions and policies to go as far as the government requires. Further, the commercial successes in C1, C2 and C3 are reaped in the alignment between the choice of markets and strong social preference signals. This sets these cases apart from A3 which is still struggling to speed up its commercialisation phase. Therefore, the following proposition is proposed:

P2: When uncertainty in the circular economy innovations is perceived as high by embedded actors, the effects of legitimacy factors on the shift towards circular economy logic are stronger than those of efficiency factors. In that condition,

P2a. Firms concerned mainly with regulatory effects tend to adopt the practice corresponding to the regulation.

P2b. Firms that are primarily driven by the cognitive factors – the commitment to upcycling food by-products and solving the sustainability issues – are likely to generate real changes. These commitment-driven firms are more likely to reap commercial success when their end markets coincide with strong social pressure.

Third, this study puts forward a proposition based on the argument of the institutional theory for the future circular transition when the uncertainty in the market and technological process recedes. Lower uncertainty in the market includes stronger customers' acceptance of products derived from food by-products. Lower technological uncertainty equates to a shorter R&D and scale-up phase to deliver products at a desirable quality that can effectively compete with the products made of virgin materials in the market. The following proposition is formed and opens the opportunities for future validations:

P3: When uncertainty in the circular economy innovations is perceived as low by embedded actors, the effects of efficiency factors on the shift towards circular economy logic are stronger than those of legitimacy factors regardless of driving sources.

Although this analytical framework is grounded in the case findings, three proposed prepositions hold value for other circular economy implementations found in the literature. Consider, for instance, the study of Gregg *et al.* (2020) on the success of the dairy biorefinery in the circular economy. The authors observed that in the early stages, adoption of the dairy biorefinery model was driven by stringent regulatory pressure on whey disposal; over time, as market and technological hurdles become lower due to rising demand for products based on diary residuals and advanced biorefinery capabilities, the sector develops a well-developed value chain for bio-residuals with a myriad of products. No government subsidies, social trends nor individual commitments are needed to engender the diffusions of the biorefinery model in the dairy industry at the moment.

Chapter 7 Conclusions and implications

This thesis set out to explore the circular economy implementations through the identifications of the practices and associated influencing factors with a focus on the management of homogeneous food by-product flow from the food processing industry and catering sector in the UK context. This chapter concludes the thesis by first providing a summary (Section 7.1), followed by conclusions with respect to three research questions (Section 7.2). Then, Section 7.3 discussed theoretical, methodological and practical contributions, before the limitations of this thesis are considered to open the avenue for future research (Section 7.4). The chapter ends with personal reflections (Section 7.5).

7.1 Thesis summary

The circular economy is an emergent concept in sustainable FSC management and contributes to offering an answer to tackle the food waste issues. The literature review section highlights the conceptual ambiguities in the extant studies of two topics under investigation: the circular economy and the food waste prevention and management while offering a unique approach to add the conceptual clarity. Despite numerous efforts in studying food waste including by-products management under the nascent circular economy context, there is a lack of a clear mechanism in how the circular economy can be operationalised to solve the food waste problems and how food waste under the circular economy is different from food waste hierarchy. As the circular economy is a difficult-to-grasp concept, it is imperative to extract and explicitly articulate the key principles of the circular economy that can be applied to the management of food by-products. In the milieu that food waste hierarchy should only be considered as a guideline, not a hard rule, this thesis contributes to filling in this gap by establishing three principles of the circular economy for food by-product management, which include high-value material production, cascading biorefinery, and green technology applications.

After reviewing the literature, a lack of empirical evidence on the valorisations of food by-products for higher value retention is unearthed in the context of both developed and developing countries. The majority of the extant literature on the topic adopted the review or experiment methods, which can be attributable to the novelty of this emergent phenomenon and only a rare number of real-world applications. This is verified in the researcher's case recruitment process. Unlike well-established manufacturing industries, not many businesses are established with the major business in the food by-product valorisations using green technologies. It is a real challenge to find and connect with the firms that satisfy the criteria specified in the case selection in both environments – the UK. The UK landscape openly favours

AD, a food-to-waste conversion route. These do not meet the case recruitment criteria set for novel food by-product valorisation under the circular economy context. After numerous recruitment efforts, six cases were purposively sampled, which contributed to providing in-depth information about the real-life context of the existing circular endeavours in food by-product management.

The extant literature underlined the research trends associated with the circular food by-product valorisations in terms of the types of desirable output products, cascading biorefinery, and technologies in the circular food waste valorisations. While the desired end products can be prioritised by borrowing the biomass value pyramid, academic papers focus on the production of different outputs from different types of by-product feedstocks, such as phenolic compounds and dietary fibres from fruit and vegetables, protein from meats and fish, and lactic acid from dairy. Food waste-derived cascading biorefinery has become increasingly popular in the academic discourse, and attention is normally paid to a single type of feedstock. Similarly, greener technologies such as SFE-CO_2, UAE, and enzyme hydrolysis have become a trendy research topic. The evidence found in six cases supports three trends identified in the literature. The choice of cases from fruits and vegetable, dairy and coffee industries validate the findings found in the literature. Not only do the technologies chosen by the sample cases reasonably reflect the alignment with the literature discourse, but the product portfolio also represents the recent interests spurred in academia.

Literature on the factors influencing the food waste valorisation efforts offers an insight into the motivators that foster these cases to engage in the circular economy transition in the first place as well as the barriers that restrict or impede these cases along their engagement process. The investigation of drivers and barriers is identified as a growing but still an underexplored topic in extant literature. While the list of factors found is highly context-laden, there is no consistent and meaningful way to classify these factors in the literature. Meanwhile, although the empirical exploration of influencers is vital to dwell on the nature of the problem and propose the targeted and specific solutions for the UK context in the circular economy transition, extant literature appears to overlook this angle. This study found a variety of influencing factors through real-world case experience. This empirical evidence further demonstrated that drivers and barriers can arise from the following sources: regulatory, social, managerial, economic and market, as well as the supply chain and technological groups. It is imperative to explore a theory-based taxonomy approach to classify these factors.

A number of theories that have been used to identify and classify factors influencing the circular economy adoptions have been encapsulated in the literature review. A comparison of multiple theoretical underpinnings elucidates the theoretical choice that best fits to answer the research question and achieve the research objectives. In this regard, an integrated institutional theory, that combines both sociological and economic variants is chosen. This thesis is the first attempt to integrate two variants into a single analytical framework and elaborate on this framework using the empirical data.

The following section will briefly shed light on the research questions and their answers.

7.2 Conclusions regarding the research questions

7.2.1 How have circular economy practices been adopted into the management of food by-products?

The empirical evidence showed that the sample cases use a mix of technological pathways to generate multiple types of high value-added end outputs, either following a mono-process or a cascading biorefinery model, as condensed in Table 18. For eggshells, a type of by-product from the dairy sector, the pharmaceutical-grade calcium carbonate is targeted using sophisticated grinding and purification approach. For fruits and vegetables, the recovery of dietary fibres and essential oils is retrieved using the drying and green extraction method. For SCG, solid fuels, biomaterials, and F&F extracts are produced in a cascading model that utilised drying, thermal and distillation technology. For potato peels and pineapple by-products, durable bio-degradable plastic and vegan leathers are generated, respectively, in accordance with the high value-added and green technology principles.

7.2.2 Why are firms being driven to be engaged in the circular practices in food by-product management?

The sampled cases were driven by a list of 11 drivers that derive from four themes: regulative, social, managerial cognitive, and economic (Table 19**Error! Reference source not found.**, Table 21). Interestingly, although the specific drivers vary from case to case, technology is not listed as a driver for all cases' engagement. Insights into the driving forces behind the case engagements elucidate what made some firms implement different practices from incumbent firms such as anaerobic digesters in the same field. Meanwhile, the appreciation of the underlying driving factors enables firms to overcome the perceived barriers to reap success in the engagement part.

Compared to the extant literature, six drivers are aligned with those found in the literature, thereby reinforcing the literature with rich empirical data. Five barriers have not been discussed in the extant literature, contributing to adding to the extant knowledge in this realm. These include the role of government in terms of providing networking opportunities and technical support, CSR enhancement, historical background, and economic drivers from low capital investment.

7.2.3 Why does their engagement in the circular practices in the food by-product management being derailed or hindered?

The empirical evidence suggests that the barriers that slow down or hinder the circular by-product stem from six themes: regulative, social, managerial cognitive, economic, technological and supply chain (Table 20**Error! Reference source not found.**, Table 22). Insights into the nature of each barrier in the sampled cases are thoroughly discussed. The major points of concern in the cases were barriers or challenges in their engagement process such as lack of market mechanisms and technological challenges, which cause deep uncertainty at the onset of their engagement. In order to alleviate these drivers and create a faster circular transition process, there is a need for collaborative efforts and the attention of practitioners, policymakers and academics.

Compared to the extant literature, nine barriers have been discussed in extant literature. Four exclusive drivers found in this study offer a valuable contribution to this field. Specifically, this study calls for (1) end-of-life re-legislation to ease market entry challenges for start-up firms in this area, (2) a change in the food by-product mindset starting with renaming “by-product” as “co-products”, (3) the willingness to challenge food waste hierarchy, (4) the solutions to alleviate logistical complexity for collecting homogeneous by-product feedstocks.

7.3 Research contributions

The thesis makes several original contributions that can be organised into three categories, which include conceptual and theoretical, methodological and practical contributions as summarised in Table 23. In the following, each category of contributions is captured in detail.

Table 23: Summary of the Research Contributions

Contributions	Aspects	Novel insights
Conceptual and theoretical	Circular economy in food by-product management	- Advance the understanding of the circular economy by extending its application in the management of food by-products via three explicit principles. - Enrich how practitioners perceive and implement the circular economy in valorising food by-products. - Add conceptual clarity to two nascent fields: circular economy and food by-product management.
	Influencing factors	- Discern drivers of and barriers to the implementation of the circular economy in the food by-product management.
	Institutional theory	- Transcend the significance of the institutional logic in the circular economy transition in food waste. - Offer an analytical framework for an integrated institutional theory that considers both legitimacy factors and efficiency ones.

Methodological	Abductive multiple case approach	- Offer rich insights into six exploratory cases that have been engaged in the circular food by-product valorisations
Praxis	Managerial implications	- Encourage an entrepreneurial and flexible mindset. - Inform managers of potential difficulties in the circular engagement as well as the potential drivers to enable the success.
	Policy implications	- Underline the significance of policy intervention to address actual concerns in the early stages of the circular transition.

Source: Created by author

7.3.1 Conceptual and theoretical contributions

Valuable conceptual and theoretical contributions have been made to operationalise the concept of circular economy in the management of food by-products in the context of six companies in the UK FSC. Specifically,

First, it moves the academic attention to the application of the emerging circular economy concept in tackling a huge volume of food by-products in the processing sector. Three explicit principles proposed in this study – higher-value creation, cascading biorefinery, and green technology – encapsulate the quintessence of the circular economy, which sets it apart from the conventional waste hierarchy in the management of food by-products.

Second, this thesis offered an intensive empirical exploration of circular food by-product management in the current context via six companies operating in the UK industry. It investigated how case companies perceive and implement the circular economy in their practices. The exploration further provided useful information regarding circular by-product management that can be used as a benchmark.

Third, this thesis provided various valuable platforms for future research in the area of circular food by-product management. Conceptual definitions, practices, drivers and barriers specified throughout the thesis lay fundamental foundations on which future researchers can build to explore various issues. These also shed light on ambiguity and confusion in both topics and advance the literature. Hence, this thesis offers a starting point for future studies in this subject.

Fourth, it explored drivers and barriers linked to the circular by-product valorisations. Although a variety of drivers and barriers have been found in literature, their links to the contextual environment such as in the UK are unknown. The context-specific drivers and barriers explored in this thesis allow key stakeholders including politicians, academics and practitioners to come up with targeted solutions to alleviate those barriers and contribute to the diffusions of the circular practices in the areas. In addition, such explorations were fed in the elaboration of the integrated institutional theory framework that is presented next.

Finally, insights from the findings have advanced the theoretical knowledge of institutional theory that is claimed as the original theoretical contribution in this study. In this regard, this study offered a coherent framework that synthesises the constituents of the practices, drivers, and barriers that support future circular economy research. This study established the institutional logic of the circular practices as legitimacy-embedded efficiency, which underlines the fundamental difference between the circular economy and the sustainability paradigm. In their very nature, they are not the same as the circular economy is an economic concept that focuses on resource efficiency and economic maximisation with less environmental harm. This study extended the framework beyond the purely institutional accounts of isomorphism and classified factors into five types, arguing that circular economy engagement is dynamically influenced by the interactions of: (i) regulatory, (ii) social (iii) cognitive (belonging to the legitimacy group), (iii) economic and supply chain, and (iv) technological factors (belonging to the efficiency group). Any factors among these types that facilitate circular economy transition are identified as drivers, whereas any factors preventing such a transition from occurring are barriers. This classification contributes to determining the relative power of legitimacy and efficiency groups in circular economy transition. When the barriers – particularly those in the efficiency group – are still plentiful, the uncertainty level in the market is high. In that condition, circular economy diffusion is likely to be influenced by the legitimacy factors, such as regulatory actions or cognitive behaviours of several individual firms. When efficiency-related barriers become less intense, circular economy dissemination is automatically generated by the efficiency improvement motive. This leads to the introduction of the moderating role of uncertainty in determining the relative powers of the two groups in circular economy transition.

7.3.2 Methodological contributions

Along with distinct contributions to the circular economy literature and institutional theory, this thesis claims to offer a significant methodological contribution. Literature indicates that studies on this area mostly utilise experiment and secondary data analysis (in form of literature review). This research, to the best of the researcher's knowledge, is the first effort to use the qualitative multiple case study approach to explore the relative experiences, viewpoints and perceptions of actors that directly adopt and implement novel food by-product management under the circular economy. This thesis collect data employing semi-structured interviews that are triangulated with direct observations and secondary data sources. This phenomenological approach enables the thesis to divulge unknown and concealed realities that might not be available in extant literature. This also enables the validation of drivers and barriers from the insiders' perspective; some of which might have been discovered in extant studies, but their methodological approach could make the findings a matter of speculations.

It is crucial to point out that the conceptual and theoretical contributions delineated above, and the practical contributions discussed next are products of methodological contribution, which is an innovative case design in this case.

7.3.3 Practical contributions

This thesis is conducive to the practice in several significant aspects by investigating a number of practical facets that give rise to wider reflection and a better understanding of circular by-product management realities. Following managerial and policy implications are drawn from the insights of the cases and the associated critical elements.

First, managers should be flexible and entrepreneurial in their choice of circular practices in the management of by-products that reflect three principles: higher-value product generation, cascading biorefinery and green technology. The researcher places special emphasis on the articulation of these three principles rather than the sole reliance on food waste hierarchy in their circular economy engagement. The most important feature of these principles is that it does not impose generic rankings on the food waste management options but opens different interpretations and more choices that are suitable for a wide range of food by-products. These choices also depend on their firms' internal capabilities and resources and should not be interpreted as the sole option available to large firms with technological and capital advantages. When higher utilisation and higher value retained from the food residues are shown to be feasible, the traditional thinking that focuses solely on feed and low added-value product creation should be altered.

Second, companies that consider integrating these circular economy principles should be wary of potential difficulties in their journey and find the drivers to overcome such difficulties to enable their success. These factors are expected to provide managers and scholars with a richer and more holistic view of multiple influencers on circular by-product valorisations. Gaining a dynamic insight into the existence of, and interactions between, factors in four groups also enables managers to customise their practices to suit their companies' requirements instead of copying circular practices applied in other firms.

Finally, this study offers policy implications as well. The need for government intervention is underlined in the early stages of food-waste valorisation due to high uncertainty (Joshi and Visvanathan, 2019; Gregg *et al.*, 2020). State agencies should tighten control on by-product valorisation activities in their areas to ensure compliance with the environmental laws and eliminate unsustainable activities. Policymakers can also play a part via a mix of their tools including laws and regulations, fiscal incentives, and public funding, as well as a flexible legislative regime supporting the launch of end products. These are crucial to lowering uncertainty for players who wish to invest in circular practices. Additionally, policymakers should carefully acknowledge and thoroughly coordinate the guidelines suggested by different categories of stakeholders, including local communities and scientific experts.

7.4 Limitations and future research directions

This study comes with limitations that offer opportunities for future research. Hence, this section aims to discuss possible avenues for future studies that can be grounded in this exploratory research. Empirical studies of the circular economy in food waste management are accorded little attention in the extant literature. Whilst this thesis partially fills this void, much remains to be investigated about how the circular economy concept can be translated into better by-product management. Three following avenues are then identified:

First, this study attempted to elaborate and ultimately refine theory rather than test it so in-depth explorations on a limited sample size have been employed. Despite efforts made to assure research quality and reduce potential biases, e.g. data triangulation from multiple sources (detailed in section 3.5) the findings derived from the study act as a pilot and require future deductive studies. This study calls for future research to use our findings to build a testable hypothesis around the factors in the framework and its subsequent verification via a quantitative enquiry (i.e., a survey administered to a larger sample for statistical testing). Specifically, the role played by uncertainty and shared logic should be underscored in the circular economy context. This study further proposes research aimed at gaining a broader understanding of the impacts of the factors on a wider range of stakeholders. Another interesting avenue would be an investigation of the most impactful drivers of, and barriers to, the circular economy transition that builds on the list provided in this article.

Second, even though the cross-sector investigation has been carried out in this thesis to shed light on the contextual differences, the sampled cases were confined to six circular by-product management efforts. Although we trust that our proposed framework will hold true for the agriculture sector in other countries, any nuances that may be found in various sectors in different countries will surely make a difference. Cross-country or cross-sector studies that shed more light on the context of developed countries may thus inform the academic discourse. Therefore, similar investigations could be carried out in other sectors at a greater number of geographical locations to examine the relationship between circular economy practices, and associated drivers and barriers.

Finally, this study invites fellow researchers to explore the perspectives of firms who have not engaged in circular economy practices to gain additional insights into their lack of momentum.

7.5 Personal reflections

A four-year PhD journey at Hull University Business School, though was quite challenging and individualistic in nature, has offered abundant time for me to do self-reflection. In general, I found a mix of stressful, frustrating, intriguing and sometimes enjoyable feelings in this full-time research journey. In this journey, I have been given a wonderful opportunity to learn how to become a competent researcher, starting with the appreciation of intellectual pluralism with various research paradigms and philosophical stances, including different ontological, epistemological and axiological assumptions. I have learned how to collect, interpret and analyse data and how to deal with my own biases, opinions and life experience that might influence the research outcomes. I also learn to navigate bureaucracy, seek support and assist others through ups and downs. From here, I have developed a genuine interest in academic research and a wish to continue pursuing this path professionally. Further, I sincerely wish that the outcomes yielded in this study will ultimately inform and assist practitioners in the transition toward the circular economy transition and innovation in food by-product management in their own firms by providing rich practically valuable insights into this concept from the cross-sectoral perspectives.

In my fourth year, I commenced to explore the prospects for pursuing a full-time academic career at a higher education institution, and this endeavour has led to my appointment to a faculty position at Lancaster University. Not only does this appointment empower me to explore different pedagogies for teaching, but it also fortifies my research interests in investigating the underlying mechanism of the radical innovation in food waste management under the landscape of the circular economy transition. Finally, I hope that the practitioners who are currently on or consider joining the circular economy movement will find the discoveries in this thesis informative and useful to envision and alleviate the associated challenges.

Reference list

2nd Environmental Action Programme1977–1981(OJ C 139, 13.6.77), European Commission, (1977).

Adil, I.H., Cetin, H., Yener, M.E., & Bayındırlı, A. (2007), "Subcritical (carbon dioxide+ ethanol) extraction of polyphenols from apple and peach pomaces, and determination of the antioxidant activities of the extracts", *The journal of supercritical fluids,* Vol.43 No.1, pp. 55-63.

Agyemang, M., Kusi-Sarpong, S., Khan, S.A., Mani, V., Rehman, S.T., & Kusi-Sarpong, H. (2019), "Drivers and barriers to circular economy implementation", *Management Decision,* Vol.57 No.4. doi:https://doi.org/10.1108/MD-11-2018-1178

Ahn, C.-B., Je, J.-Y., & Cho, Y.-S. (2012), "Antioxidant and anti-inflammatory peptide fraction from salmon byproduct protein hydrolysates by peptic hydrolysis", *Food Research International,* Vol.49 No.1, pp. 92-98.

Alexandri, M., Schneider, R., Papapostolou, H., Ladakis, D., Koutinas, A., & Venus, J. (2019), "Restructuring the conventional sugar beet industry into a novel biorefinery: fractionation and bioconversion of sugar beet pulp into succinic acid and value-added coproducts", *ACS Sustainable Chemistry & Engineering,* Vol.7 No.7, pp. 6569-6579.

Alonso-Almeida, M.d.M., & Rodríguez-Antón, J.M. (2020), "The Role of Institutional Engagement at the Macro Level in Pushing the Circular Economy in Spain and Its Regions", *International Journal of Environmental Research and Public Health,* Vol.17 No.6, pp. 2086. Retrieved from https://www.mdpi.com/1660-4601/17/6/2086

Alvesson, M., & Sandberga, J. (2009), "Generating research questions through problematization: The case of research in power, resistance and hegemony in organizations".

Armiger, S.B. (1977), "Ethics of nursing research: profile, principles, perspective", *Nursing Research,* Vol.26 No.5, pp. 330-336.

Aschemann-Witzel, J., & Stangherlin, I.D.C. (2021), "Upcycled by-product use in agri-food systems from a consumer perspective: A review of what we know, and what is missing", *Technological Forecasting and Social Change,* Vol.168, pp. 120749. doi:https://doi.org/10.1016/j.techfore.2021.120749

Bag, S., Pretorius, J.H.C., Gupta, S., & Dwivedi, Y.K. (2021), "Role of institutional pressures and resources in the adoption of big data analytics powered artificial intelligence, sustainable manufacturing practices and circular economy capabilities", *Technological Forecasting and Social Change,* Vol.163, pp. 120420. doi:https://doi.org/10.1016/j.techfore.2020.120420

Bajželj, B., Richards, K.S., Allwood, J.M., Smith, P., Dennis, J.S., Curmi, E., & Gilligan, C.A. (2014), "Importance of food-demand management for climate mitigation", *Nature Climate Change,* Vol.4 No.10, pp. 924-929.

Bakowska-Barczak, A.M., Schieber, A., & Kolodziejczyk, P. (2009), "Characterization of Canadian Black Currant (Ribes nigrum L.) Seed Oils and Residues", *Journal of Agricultural and Food Chemistry,* Vol.57 No.24, pp. 11528-11536. doi:10.1021/jf902161k

Ballesteros, L.F., Teixeira, J.A., & Mussatto, S.I. (2014), "Chemical, functional, and structural properties of spent coffee grounds and coffee silverskin", *Food and bioprocess technology,* Vol.7 No.12, pp. 3493-3503.

Banasik, A., Kanellopoulos, A., Claassen, G.D.H., Bloemhof-Ruwaard, J.M., & van der Vorst, J.G.A.J. (2017), "Closing loops in agricultural supply chains using multi-objective optimization: A case study of an industrial mushroom supply chain", *International Journal of Production Economics,* Vol.183, pp. 409-420. doi:10.1016/j.ijpe.2016.08.012

Banerjee, S., Ranganathan, V., Patti, A., & Arora, A. (2018), "Valorisation of pineapple wastes for food and therapeutic applications", *Trends in Food Science & Technology,* Vol.82, pp. 60-70. doi:10.1016/j.tifs.2018.09.024

Barbi, S., Macavei, L.I., Fuso, A., Luparelli, A.V., Caligiani, A., Ferrari, A.M., Maistrello, L., & Montorsi, M. (2020), "Valorization of seasonal agri-food leftovers through insects", *Science of the Total Environment,* Vol.709. doi:10.1016/j.scitotenv.2019.136209

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of management,* Vol.17 No.1, pp. 99-120.

Barney, J.B. (2001), "Is the resource-based "view" a useful perspective for strategic management research? Yes", *Academy of management review,* Vol.26 No.1, pp. 41-56.

Barrales, F.M., Rezende, C.A., & Martínez, J. (2015), "Supercritical CO2 extraction of passion fruit (Passiflora edulis sp.) seed oil assisted by ultrasound", *The Journal of Supercritical Fluids,* Vol.104, pp. 183-192.

Basegmez, H.I.O., Povilaitis, D., Kitrytė, V., Kraujalienė, V., Šulniūtė, V., Alasalvar, C., & Venskutonis, P.R. (2017), "Biorefining of blackcurrant pomace into high value functional ingredients using supercritical CO2, pressurized liquid and enzyme assisted extractions", *The Journal of Supercritical Fluids,* Vol.124, pp. 10-19. doi:https://doi.org/10.1016/j.supflu.2017.01.003

Bechaux, J., Gatellier, P., Le Page, J.-F., Drillet, Y., & Sante-Lhoutellier, V. (2019), "A comprehensive review of bioactive peptides obtained from animal byproducts and their applications", *Food & function,* Vol.10 No.10, pp. 6244-6266.

Bell, E., Bryman, A., & Harley, B. (2018). *Business research methods*: Oxford university press.

Ben Rebah, F., & Miled, N. (2013), "Fish processing wastes for microbial enzyme production: a review", *3 Biotech,* Vol.3 No.4, pp. 255-265. doi:10.1007/s13205-012-0099-8

Benbasat, I., Goldstein, D.K., & Mead, M. (1987), "The case research strategy in studies of information systems", *MIS quarterly*, pp. 369-386.

Benyus, J.M. (1997). *Biomimicry: Innovation Inspired by Nature*: Harper Collins.

Berbel, J., & Posadillo, A. (2018), "Review and analysis of alternatives for the valorisation of agro-industrial olive oil by-products", *Sustainability (Switzerland),* Vol.10 No.1. doi:10.3390/su10010237

Besharov, M.L., & Smith, W.K. (2014), "Multiple institutional logics in organizations: Explaining their varied nature and implications", *Academy of management review,* Vol.39 No.3, pp. 364-381.

Bhakoo, V., & Choi, T. (2013), "The iron cage exposed: Institutional pressures and heterogeneity across the healthcare supply chain", *Journal of Operations Management,* Vol.31 No.6, pp. 432-449.

Bhaskar, R. (2010). *Reclaiming reality: A critical introduction to contemporary philosophy*: Taylor & Francis.

Blaxter, L., Hughes, C., & Tight, M. (2010). *How to research*: McGraw-Hill Education (UK).

Bocken, N.M.P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016), "Product design and business model strategies for a circular economy", *Journal of Industrial and Production Engineering,* Vol.33 No.5, pp. 308-320. doi:10.1080/21681015.2016.1172124

Borrajo, P., Pateiro, M., Barba, F.J., Mora, L., Franco, D., Toldrá, F., & Lorenzo, J.M. (2019), "Antioxidant and antimicrobial activity of peptides extracted from meat by-products: A review", *Food Analytical Methods,* Vol.12 No.11, pp. 2401-2415.

Borrello, M., Lombardi, A., Pascucci, S., & Cembalo, L. (2016), "The seven challenges for transitioning into a bio-based circular economy in the agri-food sector", *Recent Patents on Food, Nutrition and Agriculture,* Vol.8 No.1, pp. 39-47. doi:10.2174/221279840801160304143939

Boumali, N.E.I., Mamine, F., Montaigne, E., & Arbouche, F. (2020), "Drivers and Barriers for the Valorization of the Apricot Pit", *International Journal of Fruit Science*, pp. 1-22. doi:10.1080/15538362.2020.1862733

Bourlakis, M.A., & Weightman, P.W.H. (2004). *Food supply chain management*: Wiley Online Library.

Braguglia, C.M., Gallipoli, A., Gianico, A., & Pagliaccia, P. (2017), "Anaerobic bioconversion of food waste into energy: A critical review", *Bioresource Technology,* Vol.248 No.Pt A, pp. 37-56.

Brandão, C. (2015). P. Bazeley and K. Jackson, qualitative data analysis with Nvivo (2013). London: Sage. In: Taylor & Francis.
Bunduchi, R., Graham, I., Smart, A., & Williams, R. (2008), "Homogeneity and heterogeneity in information technology private standard settings–the institutional account", *Technology Analysis & Strategic Management,* Vol.20 No.4, pp. 389-407.
Burrell, G., & Morgan, G. (2017). *Sociological paradigms and organisational analysis: Elements of the sociology of corporate life*. New York: Routledge.
Caldeira, C., Vlysidis, A., Fiore, G., De Laurentiis, V., Vignali, G., & Sala, S. (2020), "Sustainability of food waste biorefinery: A review on valorisation pathways, techno-economic constraints, and environmental assessment", *Bioresource Technology,* Vol.312. doi:10.1016/j.biortech.2020.123575
Caldera, H.T.S., Desha, C., & Dawes, L. (2019), "Evaluating the enablers and barriers for successful implementation of sustainable business practice in 'lean' SMEs", *Journal of Cleaner Production,* Vol.218, pp. 575-590. doi:https://doi.org/10.1016/j.jclepro.2019.01.239
Cappellozza, S., Leonardi, M.G., Savoldelli, S., Carminati, D., Rizzolo, A., Cortellino, G., Terova, G., Moretto, E., Badaile, A., Concheri, G., Saviane, A., Bruno, D., Bonelli, M., Caccia, S., Casartelli, M., & Tettamanti, G. (2019), "A first attempt to produce proteins from insects by means of a circular economy", *Animals,* Vol.9 No.5. doi:10.3390/ani9050278
Carmona-Cabello, M., Sáez-Bastante, J., Pinzi, S., & Dorado, M.P. (2019), "Optimization of solid food waste oil biodiesel by ultrasound-assisted transesterification", *Fuel,* Vol.255. doi:10.1016/j.fuel.2019.115817
Centobelli, P., Cerchione, R., & Esposito, E. (2017), "Environmental sustainability in the service industry of transportation and logistics service providers: Systematic literature review and research directions", *Transportation Research Part D: Transport and Environment,* Vol.53, pp. 454-470. doi:https://doi.org/10.1016/j.trd.2017.04.032
Chadegani, A.A., Salehi, H., Yunus, M.M., Farhadi, H., Fooladi, M., Farhadi, M., & Ebrahim, N.A. (2013), "A comparison between two main academic literature collections: Web of Science and Scopus databases", *Asian Social Science,* Vol.9 No.5, pp. 18-26.
Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*: sage.
Charmaz, K. (2014). *Constructing grounded theory*: sage.
Chen, H., Jiang, W., Yang, Y., Yang, Y., & Man, X. (2015), "Global trends of municipal solid waste research from 1997 to 2014 using bibliometric analysis", *Journal of the Air & Waste Management Association,* Vol.65 No.10, pp. 1161-1170. doi:10.1080/10962247.2015.1083913
Cherubini, F., Jungmeier, G., & Mandl, M. (2010), "IEA Bioenergy Task 42-Countries report. IEA Bioenergy Task 42 on biorefineries: Co-production of fuels, chemicals, power and materials from biomass. Final report".
Chiappetta Jabbour, C.J., Sarkis, J., Lopes de Sousa Jabbour, A.B., Scott Renwick, D.W., Singh, S.K., Grebinevych, O., Kruglianskas, I., & Filho, M.G. (2019), "Who is in charge? A review and a research agenda on the 'human side' of the circular economy", *Journal of Cleaner Production,* Vol.222, pp. 793-801. doi:https://doi.org/10.1016/j.jclepro.2019.03.038
Chiappetta Jabbour, C.J., Seuring, S., Lopes de Sousa Jabbour, A.B., Jugend, D., De Camargo Fiorini, P., Latan, H., & Izeppi, W.C. (2020), "Stakeholders, innovative business models for the circular economy and sustainable performance of firms in an emerging economy facing institutional voids", *Journal of Environmental Management,* Vol.264, pp. 110416. doi:https://doi.org/10.1016/j.jenvman.2020.110416
Claridge, T. (2018), "Functions of social capital–bonding, bridging, linking", *Social capital research,* Vol.20, pp. 1-7.
Coase, R.H. (1984), "The new institutional economics", *ZEITSCHRIFT für die gesamte Staatswissenschaft/Journal of Institutional and Theoretical Economics,* No.H. 1, pp. 229-231.

Collis, J., & Hussey, R. (2013). *Business research: A practical guide for undergraduate and postgraduate students*: Macmillan International Higher Education.

A Community Strategy for Waste Management, SEC/89/934 (Final), European Parliament Council (1989).

Conti, C., Castrica, M., Balzaretti, C.M., & Tedesco, D.E.A. (2019), "Edible earthworms in a food safety perspective: Preliminary data", *Italian Journal of Food Safety,* Vol.8 No.2. doi:10.4081/ijfs.2019.7695

Corbin, J., & Strauss, A. (2014). *Basics of qualitative research: Techniques and procedures for developing grounded theory*: Sage publications.

Corrado, S., Caldeira, C., Eriksson, M., Hanssen, O.J., Hauser, H.-E., van Holsteijn, F., Liu, G., Östergren, K., Parry, A., Secondi, L., Stenmarck, Å., & Sala, S. (2019), "Food waste accounting methodologies: Challenges, opportunities, and further advancements", *Global Food Security,* Vol.20, pp. 93-100. doi:https://doi.org/10.1016/j.gfs.2019.01.002

Corrado, S., & Sala, S. (2018), "Food waste accounting along global and European food supply chains: State of the art and outlook", *Waste Management,* Vol.79, pp. 120-131. doi:10.1016/j.wasman.2018.07.032

Council directive 75/442/EEC of 15 July 1975 on waste, European Parliament Council, (1975).

Cravotto, G., Bicchi, C., Mantegna, S., Binello, A., Tomao, V., & Chemat, F. (2011), "Extraction of kiwi seed oil: Soxhlet versus four different non-conventional techniques", *Natural product research,* Vol.25 No.10, pp. 974-981.

Creswell, J.W. (2007). *Qualitative inquiry and research design: Choosing among five approaches, 2nd ed*. Thousand Oaks, CA, US: Sage Publications, Inc.

Creswell, J.W., Klassen, A.C., Plano Clark, V.L., & Smith, K.C. (2011), "Best practices for mixed methods research in the health sciences", *Bethesda (Maryland): National Institutes of Health,* Vol.2013, pp. 541-545.

Creswell, J.W., & Creswell, J.D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications.

Cristóbal, J., Caldeira, C., Corrado, S., & Sala, S. (2018), "Techno-economic and profitability analysis of food waste biorefineries at European level", *Bioresource Technology,* Vol.259, pp. 244-252. doi:10.1016/j.biortech.2018.03.016

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*: Sage.

Cunliffe, A.L. (2003), "Reflexive inquiry in organizational research: Questions and possibilities", *Human relations,* Vol.56 No.8, pp. 983-1003.

Da Porto, C., Natolino, A., & Decorti, D. (2015), "The combined extraction of polyphenols from grape marc: Ultrasound assisted extraction followed by supercritical CO2 extraction of ultrasound-raffinate", *LWT-Food science and Technology,* Vol.61 No.1, pp. 98-104.

Dagiliene, L., Frendzel, M., Sutiene, K., & Wnuk-Pel, T. (2020), "Wise managers think about circular economy, wiser report and analyze it. Research of environmental reporting practices in EU manufacturing companies", *Journal of Cleaner Production,* Vol.274, pp. 121968. doi:https://doi.org/10.1016/j.jclepro.2020.121968

Dahiya, S., Kumar, A.N., Shanthi Sravan, J., Chatterjee, S., Sarkar, O., & Mohan, S.V. (2018), "Food waste biorefinery: Sustainable strategy for circular bioeconomy", *Bioresource Technology,* Vol.248, pp. 2-12. doi:10.1016/j.biortech.2017.07.176

Dani, S. (2015). *Food supply chain management and logistics: From farm to fork*: Kogan Page Publishers.

Davis, C.B., Aid, G., & Zhu, B. (2017), "Secondary Resources in the Bio-Based Economy: A Computer Assisted Survey of Value Pathways in Academic Literature", *Waste and Biomass Valorization,* Vol.8 No.7, pp. 2229-2246. doi:10.1007/s12649-017-9975-0

de Jesus, A., & Mendonça, S. (2018), "Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy", *Ecological Economics,* Vol.145, pp. 75-89. doi:https://doi.org/10.1016/j.ecolecon.2017.08.001

de la Caba, K., Guerrero, P., Trung, T.S., Cruz-Romero, M., Kerry, J.P., Fluhr, J., Maurer, M., Kruijssen, F., Albalat, A., Bunting, S., Burt, S., Little, D., & Newton, R. (2019), "From

seafood waste to active seafood packaging: An emerging opportunity of the circular economy", *Journal of Cleaner Production,* Vol.208, pp. 86-98. doi:10.1016/j.jclepro.2018.09.164
Del Castillo-Llamosas, A., del Río, P.G., Pérez-Pérez, A., Yáñez, R., Garrote, G., & Gullón, B. (2021), "Recent advances to recover value-added compounds from avocado by-products following a biorefinery approach", *Current Opinion in Green and Sustainable Chemistry,* Vol.28, pp. 100433. doi:https://doi.org/10.1016/j.cogsc.2020.100433
Dhillon, G.S., Kaur, S., & Brar, S.K. (2013), "Perspective of apple processing wastes as low-cost substrates for bioproduction of high value products: A review", *Renewable and Sustainable Energy Reviews,* Vol.27, pp. 789-805. doi:https://doi.org/10.1016/j.rser.2013.06.046
DiMaggio, P.J., & Powell, W.W. (1983), "The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields", *American sociological review*, pp. 147-160.
Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., & Roman, L. (2019), "Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy", *Resources, Conservation and Recycling,* Vol.141, pp. 76-98. doi:https://doi.org/10.1016/j.resconrec.2018.09.016
Donaldson, T., & Preston, L.E. (1995), "The stakeholder theory of the corporation: Concepts, evidence, and implications", *Academy of Management Review,* Vol.20 No.1, pp. 65-91.
Donner, M., Verniquet, A., Broeze, J., Kayser, K., & De Vries, H. (2021), "Critical success and risk factors for circular business models valorising agricultural waste and by-products", *Resources, Conservation and Recycling,* Vol.165, pp. 105236. doi:https://doi.org/10.1016/j.resconrec.2020.105236
Doody, O., & Noonan, M. (2013), "Preparing and conducting interviews to collect data", *Nurse researcher,* Vol.20 No.5.
Dossa, A.A., Gough, A., Batista, L., & Mortimer, K. (2020), "Diffusion of circular economy practices in the UK wheat food supply chain", *International Journal of Logistics Research and Applications*, pp. 1-20. doi:10.1080/13675567.2020.1837759
Dubey, R., Gunasekaran, A., & Samar Ali, S. (2015), "Exploring the relationship between leadership, operational practices, institutional pressures and environmental performance: A framework for green supply chain", *International Journal of Production Economics,* Vol.160, pp. 120-132. doi:https://doi.org/10.1016/j.ijpe.2014.10.001
Dubois, A., & Araujo, L. (2007), "Case research in purchasing and supply management: Opportunities and challenges", *Journal of Purchasing and Supply Management,* Vol.13 No.3, pp. 170-181. doi:https://doi.org/10.1016/j.pursup.2007.09.002
Dubois, A., & Gadde, L.-E. (2002), "Systematic combining: an abductive approach to case research", *Journal of Business Research,* Vol.55 No.7, pp. 553-560. doi:https://doi.org/10.1016/S0148-2963(00)00195-8
Dubois, A., & Gadde, L.-E. (2014), "“Systematic combining”—A decade later", *Journal of Business Research,* Vol.67 No.6, pp. 1277-1284.
Dupont-Inglis, J. (2015), "Circular Economy: All Eyes on the Juncker Commission's Next Move", *Renewable Matter. International magazine on the bioeconomy and the circular economy,* Vol.2 No.2.
Easterby-Smith, M., Lyles, M.A., & Peteraf, M.A. (2009), "Dynamic Capabilities: Current Debates and Future Directions", *British Journal of Management,* Vol.20 No.s1, pp. S1-S8. doi:10.1111/j.1467-8551.2008.00609.x
Easterby-Smith, M., Thorpe, R., & Jackson, P.R. (2012). *Management research*: Sage.
Ehrenfeld, J., & Gertler, N. (1997), "Industrial ecology in practice: the evolution of interdependence at Kalundborg", *Journal of industrial Ecology,* Vol.1 No.1, pp. 67-79.
Eisenhardt, K.M. (1989), "Building theories from case study research", *Academy of management review,* Vol.14 No.4, pp. 532-550.
Ekinci, M.S., & Gürü, M. (2014), "Extraction of oil and β-sitosterol from peach (Prunus persica) seeds using supercritical carbon dioxide", *The Journal of Supercritical Fluids,* Vol.92, pp. 319-323. doi:https://doi.org/10.1016/j.supflu.2014.06.004

Elkjaer, B., & Simpson, B. (2011). Pragmatism: A lived and living philosophy. What can it offer to contemporary organization theory? In *Philosophy and organization theory*: Emerald Group Publishing Limited.
Ellen MacArthur Foundation. (2012), "Towards the circular economy: an economic and business rationale for an accelerated transition", available at: https://www.werktrends.nl/app/uploads/2015/06/Rapport_McKinsey-Towards_A_Circular_Economy.pdf
Ellen MacArthur Foundation. (2015), "Towards a Circular Economy: Business rationale for an accelerated transition", available at: https://www.ellenmacarthurfoundation.org/publications/towards-a-circular-economy-business-rationale-for-an-accelerated-transition
Ellen MacArthur Foundation. (2016), "The New Plastics Economy: Rethinking the future of plastics & catalysing action". Retrieved from https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics-catalysing-action
Ellen MacArthur Foundation. (2017), "A New Textiles Economy: Redesigning fashion's future". Retrieved from https://www.ellenmacarthurfoundation.org/publications/a-new-textiles-economy-redesigning-fashions-future
Ellen MacArthur Foundation. (2018), "The Circular Economy Opportunity for Urban and Industrial Innovation in China" available at: https://www.ellenmacarthurfoundation.org/publications/chinareport
Ellen MacArthur Foundation. (2019), "Cities and Circular Economy for Food" available at: https://www.ellenmacarthurfoundation.org/publications/cities-and-circular-economy-for-food
Ellen MacArthur Foundation. (2020), "Financing the Circular Economy - Capturing the opportunity". Retrieved from https://www.ellenmacarthurfoundation.org/publications/financing-the-circular-economy-capturing-the-opportunity
Ellram, L.M. (1996), "The use of the case study method in logistics research", *Journal of business logistics,* Vol.17 No.2, pp. 93-93.
Eriksson, D., & Engström, A. (2021), "Using critical realism and abduction to navigate theory and data in operations and supply chain management research", *Supply Chain Management: An International Journal,* Vol.26 No.2, pp. 224-239. doi:10.1108/SCM-03-2020-0091
European Commission. (2015). *Closing the loop - An EU action plan for the Circular Economy*.
European Commission. (2020), "Circular Economy Action Plan for a cleaner and more competitive Europe" available at: https://ec.europa.eu/environment/pdf/circular-economy/new_circular_economy_action_plan.pdf
European Parliament. (2020), "Changing how we produce and consume: New Circular Economy Action Plan shows the way to a climate-neutral, competitive economy of empowered consumers" available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_420
FAO. (2011), "Global food losses and food waste – Extent, causes and prevention", Rome, available at: http://www.fao.org/3/a-i2697e.pdf
FAO. (2013), "Food Wastage Footprint. Impact on Natural Resources" available at: http://www.fao.org/publications/card/en/c/000d4a32-7304-5785-a2f1-f64c6de8e7a2/
FAO. (2014), "Food Wastage Footprint: Full cost-accounting" available at: http://www.fao.org/publications/card/en/c/5e7c4154-2b97-4ea5-83a7-be9604925a24/
FAO. (2019), "The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. " available at: http://www.fao.org/state-of-food-agriculture/en/
FAO, IFAD, UNICEF, WFP, & WHO. (2018), "The State of Food Security and Nutrition in the World 2018: Building climate resilience for food security and nutrition", Rome, available at: http://www.fao.org/3/I9553EN/i9553en.pdf

Ferdosh, S., Sarker, Z.I., Norulaini, N., Oliveira, A., Yunus, K., Chowdury, A.J., Akanda, J., & Omar, M. (2015), "Quality of tuna fish oils extracted from processing the by‐products of three species of neritic tuna using supercritical carbon dioxide", *Journal of Food Processing and Preservation,* Vol.39 No.4, pp. 432-441.

Ferrando, T., & Mansuy, J. (2018), "The European action against food loss and waste: Co-regulation and collisions on the way to the sustainable development goals", *Yearbook of European Law,* Vol.37, pp. 424-454.

Ferrazzi, G., Ventura, V., Balzaretti, C., & Castrica, M. (2019), "Exploring the Landscape of Innovative from Food to Feed Strategies: A Review", *International Journal on Food System Dynamics,* Vol.10, pp. 287-297.

Fink, A. (2019). *Conducting research literature reviews: From the internet to paper*: Sage publications.

Flanagan, K., Clowes, A., Lipinski, B., Goodwin, L., & Swannell, R. (2018), "SDG Target 12.3 on food loss and waste: 2018 progress report", *An annual update on behalf of Champions,* Vol.12.

Fletcher, A.J. (2017), "Applying critical realism in qualitative research: methodology meets method", *International journal of social research methodology,* Vol.20 No.2, pp. 181-194.

Fleetwood, S. (2005), "Ontology in organization and management studies: A critical realist perspective", *Organization,* Vol.12 No.2, pp. 197-222.

FLW Protocol. (2016), "Food Loss and Waste Accounting and Reporting Standard" available at: https://www.flwprotocol.org/wp-content/uploads/2017/05/FLW_Standard_final_2016.pdf

Freeman, R.E. (2010). *Strategic management: A stakeholder approach*: Cambridge university press.

Friedman, A.L., & Miles, S. (2006). *Stakeholders: Theory and practice*: Oxford University Press on Demand.

Frosch, R.A., & Gallopoulos, N.E. (1989), "Strategies for manufacturing", *Scientific American,* Vol.261 No.3, pp. 144-153.

FUSIONS. (2014), "FUSIONS Definitional Framework for Food Waste"

Galanakis, C.M. (2012), "Recovery of high added-value components from food wastes: Conventional, emerging technologies and commercialized applications", *Trends in Food Science & Technology,* Vol.26 No.2, pp. 68-87.

Garcia-Garcia, G., Woolley, E., & Rahimifard, S. (2015), "A framework for a more efficient approach to food waste management", *International Journal of Food Engineering,* Vol.1 No.1, pp. 65-72.

Gedam, V.V., Raut, R.D., Lopes de Sousa Jabbour, A.B., Tanksale, A.N., & Narkhede, B.E. (2021), "Circular economy practices in a developing economy: Barriers to be defeated", *Journal of Cleaner Production,* Vol.311, pp. 127670. doi:https://doi.org/10.1016/j.jclepro.2021.127670

Geissdoerfer, M., Savaget, P., Bocken, N.M.P., & Hultink, E.J. (2017), "The Circular Economy – A new sustainability paradigm?", *Journal of Cleaner Production,* Vol.143, pp. 757-768. doi:https://doi.org/10.1016/j.jclepro.2016.12.048

Geng, Y., & Doberstein, B. (2008), "Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'", *The International Journal of Sustainable Development & World Ecology,* Vol.15 No.3, pp. 231-239.

Genovese, A., Acquaye, A.A., Figueroa, A., & Koh, S.C.L. (2017), "Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications", *Omega,* Vol.66, pp. 344-357. doi:10.1016/j.omega.2015.05.015

Ghinoi, S., Silvestri, F., & Steiner, B. (2019), "The role of local stakeholders in disseminating knowledge for supporting the circular economy: a network analysis approach", *Ecological Economics,* Vol.169.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016), "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems", *Journal of*

Cleaner Production, Vol.114, pp. 11-32. doi:https://doi.org/10.1016/j.jclepro.2015.09.007

Gimenez, C., & Tachizawa, E.M. (2012), "Extending sustainability to suppliers: a systematic literature review", *Supply Chain Management: an international journal*.

Girotto, F., Alibardi, L., & Cossu, R. (2015), "Food waste generation and industrial uses: a review", *Waste Management,* Vol.45, pp. 32-41.

Glaser, B.G., Strauss, A.L., & Strutzel, E. (1968), "The Discovery of Grounded Theory; Strategies for Qualitative Research", *Nursing Research,* Vol.17 No.4, pp. 364.

Gómez-Guillén, M., Pérez-Mateos, M., Gómez-Estaca, J., López-Caballero, E., Giménez, B., & Montero, P. (2009), "Fish gelatin: a renewable material for developing active biodegradable films", *Trends in Food Science & Technology,* Vol.20 No.1, pp. 3-16.

Gorzen-Mitka, I., Bilska, B., Tomaszewska, M., & Kolozyn-Krajewska, D. (2020), "Mapping the Structure of Food Waste Management Research: A Co-Keyword Analysis", *International Journal of Environmental Research and Public Health,* Vol.17 No.13. doi:10.3390/ijerph17134798

Govindan, K., & Hasanagic, M. (2018), "A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective", *International Journal of Production Research,* Vol.56 No.1-2, pp. 278-311. doi:https://doi.org/10.1080/00207543.2017.1402141

Graedel, T.E. (1996), "On the concept of industrial ecology", *Annual Review of Energy and the Environment,* Vol.21 No.1, pp. 69-98.

Greenwood, R., Díaz, A.M., Li, S.X., & Lorente, J.C. (2010), "The multiplicity of institutional logics and the heterogeneity of organizational responses", *Organization science,* Vol.21 No.2, pp. 521-539.

Greenwood, R., & Hinings, C.R. (1996), "Understanding radical organizational change: Bringing together the old and the new institutionalism", *Academy of management review,* Vol.21 No.4, pp. 1022-1054.

Gregg, J.S., Jürgens, J., Happel, M.K., Strøm-Andersen, N., Tanner, A.N., Bolwig, S., & Klitkou, A. (2020), "Valorization of bio-residuals in the food and forestry sectors in support of a circular bioeconomy: A review", *Journal of Cleaner Production,* Vol.267, pp. 122093. doi:https://doi.org/10.1016/j.jclepro.2020.122093

Guba, E.G., & Lincoln, Y.S. (2005), "Paradigmatic controversies, contradictions, and emerging confluences".

Gullón, P., Gullón, B., Astray, G., Carpena, M., Fraga-Corral, M., Prieto, M.A., & Simal-Gandara, J. (2020), "Valorization of by-products from olive oil industry and added-value applications for innovative functional foods", *Food Research International,* Vol.137, pp. 109683. doi:https://doi.org/10.1016/j.foodres.2020.109683

Gummesson, E. (2007), "Access to reality: observations on observational methods", *Qualitative Market Research: An International Journal*.

Gupta, S., Chen, H., Hazen, B.T., Kaur, S., & Gonzalez, E.D.R.S. (2019), "Circular economy and big data analytics: A stakeholder perspective", *Technological Forecasting and Social Change,* Vol.144, pp. 466-474.

Hart, S.L. (1995), "A natural-resource-based view of the firm", *Academy of management review,* Vol.20 No.4, pp. 986-1014.

Haunschild, P.R., & Miner, A.S. (1997), "Modes of Interorganizational Imitation: The Effects of Outcome Salience and Uncertainty", *Administrative Science Quarterly,* Vol.42 No.3, pp. 472-500. doi:https://doi.org/10.2307/2393735

Haynes, K. (2012), "Reflexivity in qualitative research", *Qualitative organizational research: Core methods and current challenges*, pp. 72-89.

Hoffman, A.J. (2001), "Linking organizational and field-level analyses: The diffusion of corporate environmental practice", *Organization & environment,* Vol.14 No.2, pp. 133-156.

Homrich, A.S., Galvão, G., Abadia, L.G., & Carvalho, M.M. (2018), "The circular economy umbrella: Trends and gaps on integrating pathways", *Journal of Cleaner Production,* Vol.175, pp. 525-543. doi:https://doi.org/10.1016/j.jclepro.2017.11.064

Hu, J., Xiao, Z., Zhou, R., Deng, W., Wang, M., & Ma, S. (2011), "Ecological utilization of leather tannery waste with circular economy model", *Journal of Cleaner Production,* Vol.19 No.2, pp. 221-228. doi:https://doi.org/10.1016/j.jclepro.2010.09.018

Ingrao, C., Faccilongo, N., Di Gioia, L., & Messineo, A. (2018), "Food waste recovery into energy in a circular economy perspective: A comprehensive review of aspects related to plant operation and environmental assessment", *Journal of Cleaner Production,* Vol.184, pp. 869-892. doi:10.1016/j.jclepro.2018.02.267

Jabbour, C.J.C., Jabbour, A.B.L.d.S., Sarkis, J., & Filho, M.G. (2019), "Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda", *Technological Forecasting and Social Change,* Vol.144, pp. 546-552. doi:https://doi.org/10.1016/j.techfore.2017.09.010

Jakhar Suresh, K., Mangla Sachin, K., Luthra, S., & Kusi-Sarpong, S. (2019), "When stakeholder pressure drives the circular economy: Measuring the mediating role of innovation capabilities", *Management Decision,* Vol.57 No.4, pp. 904-920. doi:10.1108/MD-09-2018-0990

Johnson, R., & Cureton, A. (2021). Kant’s Moral Philosophy. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Spring 2021 Edition ed.).

Jongjareonrak, A., Rawdkuen, S., Chaijan, M., Benjakul, S., Osako, K., & Tanaka, M. (2010), "Chemical compositions and characterisation of skin gelatin from farmed giant catfish (Pangasianodon gigas)", *LWT-Food Science and Technology,* Vol.43 No.1, pp. 161-165.

Joshi, P., & Visvanathan, C. (2019), "Sustainable management practices of food waste in Asia: Technological and policy drivers", *Journal of Environmental Management,* Vol.247, pp. 538-550. doi:https://doi.org/10.1016/j.jenvman.2019.06.079

Kallel, F., & Ellouz Chaabouni, S. (2017), "Perspective of garlic processing wastes as low-cost substrates for production of high-added value products: A review", *Environmental Progress & Sustainable Energy,* Vol.36 No.6, pp. 1765-1777. doi:https://doi.org/10.1002/ep.12649

Kant, I. (2017). *Kant: The Metaphysics of Morals* (M. Gregor, Trans. L. Denis Ed. 2 ed.). Cambridge: Cambridge University Press.

Kanters, J. (2020), "Circular Building Design: An Analysis of Barriers and Drivers for a Circular Building Sector", *Buildings,* Vol.10 No.4, pp. 77. Retrieved from https://www.mdpi.com/2075-5309/10/4/77

Kauppi, K. (2013), "Extending the use of institutional theory in operations and supply chain management research", *International Journal of Operations & Production Management,* Vol.33 No.10, pp. 1318-1345. doi:10.1108/IJOPM-10-2011-0364

Keegan, D., Kretschmer, B., Elbersen, B., & Panoutsou, C. (2013), "Cascading use: a systematic approach to biomass beyond the energy sector", *Biofuels, Bioproducts and Biorefining,* Vol.7 No.2, pp. 193-206. doi:https://doi.org/10.1002/bbb.1351

Kelemen, M.L., & Rumens, N. (2008). *An introduction to critical management research*: Sage.

Kenneth, B. (1965), "Earth as a space ship", *Washington State University Committee on Space Sciences*.

Ketokivi, M., & Choi, T. (2014), "Renaissance of case research as a scientific method", *Journal of Operations Management,* Vol.32 No.5, pp. 232-240.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018), "Barriers to the Circular Economy: Evidence From the European Union (EU)", *Ecological Economics,* Vol.150, pp. 264-272. doi:https://doi.org/10.1016/j.ecolecon.2018.04.028

Kirchherr, J., Reike, D., & Hekkert, M. (2017), "Conceptualizing the circular economy: An analysis of 114 definitions", *Resources, Conservation and Recycling,* Vol.127, pp. 221-232. doi:https://doi.org/10.1016/j.resconrec.2017.09.005

Kokossis, A.C., & Koutinas, A.A. (2012), "Food waste as a renewable raw material for the development of integrated biorefineries: current status and future potential", *Integrated Biorefineries: Design, Analysis, and Optimization*, pp. 469.

Kosseva, M.R. (2011). Management and processing of food wastes. In M. Moo-Young (Ed.), *Comprehensive Biotechnology, Environmental Biotechnology and Safety* (Vol. 6, pp. 595-603).

Kourmentza, C., Economou, C.N., Tsafrakidou, P., & Kornaros, M. (2018), "Spent coffee grounds make much more than waste: Exploring recent advances and future exploitation strategies for the valorization of an emerging food waste stream", *Journal of Cleaner Production,* Vol.172, pp. 980-992. doi:10.1016/j.jclepro.2017.10.088

Kummu, M., de Moel, H., Porkka, M., Siebert, S., Varis, O., & Ward, P.J. (2012), "Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use", *Science of the Total Environment,* Vol.438, pp. 477-489. doi:https://doi.org/10.1016/j.scitotenv.2012.08.092

Kvale, S. (1994). *Interviews: An introduction to qualitative research interviewing*: Sage Publications, Inc.

Kyriakopoulos, G., Kapsalis, V., Aravossis, K., Zamparas, M., & Mitsikas, A. (2019), "Evaluating Circular Economy under a Multi-Parametric Approach: A Technological Review", *Sustainability,* Vol.11 No.21. doi:10.3390/su11216139

Lahti, T., Wincent, J., & Parida, V. (2018), "A Definition and Theoretical Review of the Circular Economy, Value Creation, and Sustainable Business Models: Where Are We Now and Where Should Research Move in the Future?", *Sustainability,* Vol.10 No.8, pp. 2799. Retrieved from https://www.mdpi.com/2071-1050/10/8/2799

Lapeña, D., Vuoristo, K.S., Kosa, G., Horn, S.J., & Eijsink, V.G. (2018), "Comparative assessment of enzymatic hydrolysis for valorization of different protein-rich industrial byproducts", *Journal of agricultural and food chemistry,* Vol.66 No.37, pp. 9738-9749.

Lebersorger, S., & Salhofer, S. (2003). Generation and diversion of bio waste in private households and potential for waste minimisation. In *Recycling and Reuse of Waste Materials* (pp. 107-116): Thomas Telford Publishing.

Leder, N., Kumar, M., & Rodrigues, V.S. (2020), "Influential factors for value creation within the Circular Economy: Framework for Waste Valorisation", *Resources, Conservation and Recycling,* Vol.158, pp. 104804. doi:https://doi.org/10.1016/j.resconrec.2020.104804

Leech, N.L., & Onwuegbuzie, A.J. (2011), "Beyond constant comparison qualitative data analysis: Using NVivo", *School Psychology Quarterly,* Vol.26 No.1, pp. 70.

Lieder, M., & Rashid, A. (2016), "Towards circular economy implementation: a comprehensive review in context of manufacturing industry", *Journal of cleaner production,* Vol.115, pp. 36-51.

Lin, N. (2002). *Social capital: A theory of social structure and action* (Vol. 19): Cambridge university press.

Liu, J., Feng, Y., Zhu, Q., & Sarkis, J. (2018), "Green supply chain management and the circular economy", *International Journal of Physical Distribution & Logistics Management*.

Lucarini, M., Zuorro, A., Di Lena, G., Lavecchia, R., Durazzo, A., Benedetti, B., & Lombardi-Boccia, G. (2020), "Sustainable Management of Secondary Raw Materials from the Marine Food-Chain: A Case-Study Perspective", *Sustainability,* Vol.12 No.21, pp. 8997. Retrieved from https://www.mdpi.com/2071-1050/12/21/8997

Lucas, M.T., & Noordewier, T.G. (2016), "Environmental management practices and firm financial performance: The moderating effect of industry pollution-related factors", *International Journal of Production Economics,* Vol.175, pp. 24-34. doi:https://doi.org/10.1016/j.ijpe.2016.02.003

Lyu, F., Luiz, S.F., Azeredo, D.R.P., Cruz, A.G., Ajlouni, S., & Ranadheera, C.S. (2020), "Apple Pomace as a Functional and Healthy Ingredient in Food Products: A Review", *Processes,* Vol.8 No.3, pp. 319. Retrieved from https://www.mdpi.com/2227-9717/8/3/319

Maina, S., Kachrimanidou, V., & Koutinas, A. (2017), "A roadmap towards a circular and sustainable bioeconomy through waste valorization", *Current Opinion in Green and Sustainable Chemistry,* Vol.8, pp. 18-23. doi:10.1016/j.cogsc.2017.07.007

Mani, V., & Gunasekaran, A. (2018), "Four forces of supply chain social sustainability adoption in emerging economies", *International Journal of Production Economics,* Vol.199, pp. 150-161.
Mantere, S., & Ketokivi, M. (2013), "Reasoning in organization science", *Academy of management review,* Vol.38 No.1, pp. 70-89.
Maran, J.P., Sivakumar, V., Thirugnanasambandham, K., & Sridhar, R. (2014), "Microwave assisted extraction of pectin from waste Citrullus lanatus fruit rinds", *Carbohydrate polymers,* Vol.101, pp. 786-791.
Marshall, C., & Rossman, G.B. (2014). *Designing qualitative research*: Sage publications.
Mata, T.M., Martins, A.A., & Caetano, N.S. (2018), "Bio-refinery approach for spent coffee grounds valorization", *Bioresource Technology,* Vol.247, pp. 1077-1084. doi:https://doi.org/10.1016/j.biortech.2017.09.106
Matharu, A.S., de Melo, E.M., & Houghton, J.A. (2016), "Opportunity for high value-added chemicals from food supply chain wastes", *Bioresource Technology,* Vol.215, pp. 123-130. doi:https://doi.org/10.1016/j.biortech.2016.03.039
Mathews, J.A., & Tan, H. (2011), "Progress Toward a Circular Economy in China", *Journal of Industrial Ecology,* Vol.15 No.3, pp. 435-457. doi:https://doi.org/10.1111/j.1530-9290.2011.00332.x
Mayring, P. (2008), "Qualitative content analysis: theoretical foundation, basic procedures and software solution".
McDonough, W., & Braungart, M. (2010). *Cradle to Cradle: Remaking the Way We Make Things*: Farrar, Straus and Giroux.
McGovern, T., Small, A., & Hicks, C. (2017), "Diffusion of process improvement methods in European SMEs", *International Journal of Operations & Production Management,* Vol.37 No.5, pp. 607-629. doi:10.1108/IJOPM-11-2015-0694
Meherishi, L., Narayana, S.A., & Ranjani, K.S. (2019), "Sustainable packaging for supply chain management in the circular economy: A review", *Journal of Cleaner Production,* Vol.237, pp. 117582. doi:https://doi.org/10.1016/j.jclepro.2019.07.057
Merli, R., Preziosi, M., & Acampora, A. (2018), "How do scholars approach the circular economy? A systematic literature review", *Journal of Cleaner Production,* Vol.178, pp. 703-722. doi:https://doi.org/10.1016/j.jclepro.2017.12.112
Meyer, J.W., & Rowan, B. (1977), "Institutionalized organizations: Formal structure as myth and ceremony", *American journal of sociology,* Vol.83 No.2, pp. 340-363.
Miemczyk, J. (2008), "An exploration of institutional constraints on developing end-of-life product recovery capabilities", *International Journal of Production Economics,* Vol.115 No.2, pp. 272-282. doi:https://doi.org/10.1016/j.ijpe.2008.04.013
Miles, M.B., Huberman, A.M., & Saldana, J. (2018). *Qualitative Data Analysis: A Methods Sourcebook*: SAGE Publications.
Mir, R., Willmott, H., & Greenwood, M. (2015). *The Routledge companion to philosophy in organization studies*: Routledge.
Mirabella, N., Castellani, V., & Sala, S. (2014), "Current options for the valorization of food manufacturing waste: A review", *Journal of Cleaner Production,* Vol.65, pp. 28-41. doi:10.1016/j.jclepro.2013.10.051
Mishra, J.L., Chiwenga, K.D., & Ali, K. (2019), "Collaboration as an enabler for circular economy: a case study of a developing country", *Management Decision,* Vol.ahead-of-print No.ahead-of-print. doi:10.1108/MD-10-2018-1111
Mitchell, R.K., Agle, B.R., & Wood, D.J. (1997), "Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts", *Academy of management review,* Vol.22 No.4, pp. 853-886.
Mokhtar, A.R.M., Genovese, A., Brint, A., & Kumar, N. (2019), "Supply chain leadership: A systematic literature review and a research agenda", *International Journal of Production Economics,* Vol.216, pp. 255-273. doi:https://doi.org/10.1016/j.ijpe.2019.04.001
Monteiro, A., Paquincha, D., Martins, F., Queirós, R.P., Saraiva, J.A., Švarc-Gajić, J., Nastić, N., Delerue-Matos, C., & Carvalho, A.P. (2018), "Liquid by-products from fish canning

industry as sustainable sources of ω3 lipids", *Journal of environmental management,* Vol.219, pp. 9-17.

Moorthy, I.G., Maran, J.P., Muneeswari, S., Naganyashree, S., & Shivamathi, C. (2015), "Response surface optimization of ultrasound assisted extraction of pectin from pomegranate peel", *International journal of biological macromolecules,* Vol.72, pp. 1323-1328.

Morgan, D.L. (2007), "Paradigms lost and pragmatism regained: Methodological implications of combining qualitative and quantitative methods", *Journal of mixed methods research,* Vol.1 No.1, pp. 48-76.

Morioka, T., Tsunemi, K., Yamamoto, Y., Yabar, H., & Yoshida, N. (2005), "Eco‐efficiency of advanced loop‐closing systems for vehicles and household appliances in Hyogo eco‐town", *Journal of Industrial Ecology,* Vol.9 No.4, pp. 205-221.

Morone, P., Koutinas, A., Gathergood, N., Arshadi, M., & Matharu, A. (2019), "Food waste: Challenges and opportunities for enhancing the emerging bio-economy", *Journal of Cleaner Production,* Vol.221, pp. 10-16. doi:10.1016/j.jclepro.2019.02.258

Morseletto, P. (2020), "Restorative and regenerative: Exploring the concepts in the circular economy", *Journal of Industrial Ecology,* Vol.24 No.4, pp. 763-773. doi:https://doi.org/10.1111/jiec.12987

Murray, A., Skene, K., & Haynes, K. (2017), "The circular economy: an interdisciplinary exploration of the concept and application in a global context", *Journal of business ethics,* Vol.140 No.3, pp. 369-380.

Mussatto, S.I., Moncada, J., Roberto, I.C., & Cardona, C.A. (2013), "Techno-economic analysis for brewer's spent grains use on a biorefinery concept: The Brazilian case", *Bioresource Technology,* Vol.148, pp. 302-310. doi:https://doi.org/10.1016/j.biortech.2013.08.046

Naghshineh, M., Olsen, K., & Georgiou, C.A. (2013), "Sustainable production of pectin from lime peel by high hydrostatic pressure treatment", *Food chemistry,* Vol.136 No.2, pp. 472-478.

Näslund, D. (2002), "Logistics needs qualitative research–especially action research", *International Journal of Physical Distribution & Logistics Management*.

Nawaz, A., Li, E., Irshad, S., Xiong, Z., Xiong, H., Shahbaz, H.M., & Siddique, F. (2020), "Valorization of fisheries by-products: Challenges and technical concerns to food industry", *Trends in Food Science & Technology,* Vol.99, pp. 34-43. doi:https://doi.org/10.1016/j.tifs.2020.02.022

Neuman, W.L., & Robson, K. (2014). *Basics of social research*: Pearson Canada Toronto.

Nobre, G.C., & Tavares, E. (2017), "Scientific literature analysis on big data and internet of things applications on circular economy: a bibliometric study", *Scientometrics,* Vol.111 No.1, pp. 463-492.

Oliveira, D.A., Benelli, P., & Amante, E.R. (2013), "A literature review on adding value to solid residues: egg shells", *Journal of Cleaner Production,* Vol.46, pp. 42-47. doi:https://doi.org/10.1016/j.jclepro.2012.09.045

Ong, K.L., Kaur, G., Pensupa, N., Uisan, K., & Lin, C.S.K. (2018), "Trends in food waste valorization for the production of chemicals, materials and fuels: Case study South and Southeast Asia", *Bioresource Technology,* Vol.248, pp. 100-112. doi:https://doi.org/10.1016/j.biortech.2017.06.076

Ordanini, A., Rubera, G., & DeFillippi, R. (2008), "The many moods of inter-organizational imitation: A critical review", *International Journal of Management Reviews,* Vol.10 No.4, pp. 375-398. doi:https://doi.org/10.1111/j.1468-2370.2008.00233.x

Pal, G.K., & Suresh, P.V. (2016), "Sustainable valorisation of seafood by-products: Recovery of collagen and development of collagen-based novel functional food ingredients", *Innovative Food Science & Emerging Technologies,* Vol.37, pp. 201-215. doi:https://doi.org/10.1016/j.ifset.2016.03.015

Papargyropoulou, E., Lozano, R., K. Steinberger, J., Wright, N., & Ujang, Z.b. (2014), "The food waste hierarchy as a framework for the management of food surplus and food waste", *Journal of Cleaner Production,* Vol.76, pp. 106-115. doi:10.1016/j.jclepro.2014.04.020

Pagell, M., & Wu, Z. (2009), "Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars", *Journal of Supply Chain Management,* Vol.45 No.2, pp. 37-56. doi:https://doi.org/10.1111/j.1745-493X.2009.03162.x

Pauli, G.A. (2010). *The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs*: Paradigm Publications.

Pearce, D.W., & Turner, R.K. (1990). *Economics of natural resources and the environment*: JHU press.

Perry, C. (1998), "Processes of a case study methodology for postgraduate research in marketing", *European journal of marketing*.

Perussello, C.A., Zhang, Z., Marzocchella, A., & Tiwari, B.K. (2017), "Valorization of Apple Pomace by Extraction of Valuable Compounds", *Comprehensive Reviews in Food Science and Food Safety,* Vol.16 No.5, pp. 776-796. doi:https://doi.org/10.1111/1541-4337.12290

Piekkari, R., Welch, C., & Paavilainen, E. (2009), "The case study as disciplinary convention: Evidence from international business journals", *Organizational research methods,* Vol.12 No.3, pp. 567-589.

Pingret, D., Fabiano-Tixier, A.-S., Le Bourvellec, C., Renard, C.M., & Chemat, F. (2012), "Lab and pilot-scale ultrasound-assisted water extraction of polyphenols from apple pomace", *Journal of Food Engineering,* Vol.111 No.1, pp. 73-81.

Plakoyiannaki, E., & Budhwar, P. (2021). From convention to alternatives: rethinking qualitative research in management scholarship. In (Vol. 32, pp. 3-6).

Putnam, R.D. (1995), "Tuning in, tuning out: The strange disappearance of social capital in America", *PS: Political science & politics,* Vol.28 No.4, pp. 664-683.

Quina, M.J., Soares, M.A.R., & Quinta-Ferreira, R. (2017), "Applications of industrial eggshell as a valuable anthropogenic resource", *Resources, Conservation and Recycling,* Vol.123, pp. 176-186. doi:https://doi.org/10.1016/j.resconrec.2016.09.027

Raak, N., Symmank, C., Zahn, S., Aschemann-Witzel, J., & Rohm, H. (2017), "Processing- and product-related causes for food waste and implications for the food supply chain", *Waste Management,* Vol.61, pp. 461-472. doi:https://doi.org/10.1016/j.wasman.2016.12.027

Rama, G.R., Kuhn, D., Beux, S., Maciel, M.J., & Volken de Souza, C.F. (2019), "Potential applications of dairy whey for the production of lactic acid bacteria cultures", *International Dairy Journal,* Vol.98, pp. 25-37. doi:https://doi.org/10.1016/j.idairyj.2019.06.012

Ranta, V., Aarikka-Stenroos, L., Ritala, P., & Mäkinen, S.J. (2018), "Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe", *Resources, Conservation and Recycling,* Vol.135, pp. 70-82. doi:https://doi.org/10.1016/j.resconrec.2017.08.017

Rathore, D., Nizami, A.-S., Singh, A., & Pant, D. (2016), "Key issues in estimating energy and greenhouse gas savings of biofuels: challenges and perspectives", *Biofuel Research Journal,* Vol.3 No.2, pp. 380-393.

Reay, T., & Hinings, C.R. (2009), "Managing the rivalry of competing institutional logics", *Organization studies,* Vol.30 No.6, pp. 629-652.

Reed, M. (2005), "Reflections on the 'realist turn'in organization and management studies", *Journal of Management studies,* Vol.42 No.8, pp. 1621-1644.

Ruiz-Montañez, G., Ragazzo-Sánchez, J., Calderón-Santoyo, M., Velazquez-De La Cruz, G., De León, J.R., & Navarro-Ocaña, A. (2014), "Evaluation of extraction methods for preparative scale obtention of mangiferin and lupeol from mango peels (Mangifera indica L.)", *Food chemistry,* Vol.159, pp. 267-272.

Russell, M., Gianoli, A., & Grafakos, S. (2020), "Getting the ball rolling: an exploration of the drivers and barriers towards the implementation of bottom-up circular economy initiatives in Amsterdam and Rotterdam", *Journal of Environmental Planning and Management,* Vol.63 No.11, pp. 1903-1926. doi:10.1080/09640568.2019.1690435

Saavedra, Y.M.B., Iritani, D.R., Pavan, A.L.R., & Ometto, A.R. (2018), "Theoretical contribution of industrial ecology to circular economy", *Journal of Cleaner Production,* Vol.170, pp. 1514-1522. doi:https://doi.org/10.1016/j.jclepro.2017.09.260

Sadhukhan, J., Dugmore, T.I.J., Matharu, A., Martinez-Hernandez, E., Aburto, J., Rahman, P.K.S.M., & Lynch, J. (2020), "Perspectives on "game changer" global challenges for sustainable 21st century: Plant-based diet, unavoidable food waste biorefining, and circular economy", *Sustainability (Switzerland),* Vol.12 No.5. doi:10.3390/su12051976

Sakai, S.-i., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., Tomoda, K., Peeler, M.V., Wejchert, J., & Schmid-Unterseh, T. (2011), "International comparative study of 3R and waste management policy developments", *Journal of Material Cycles and Waste Management,* Vol.13 No.2, pp. 86-102.

Saldaña, J. (2015). *The coding manual for qualitative researchers*: Sage.

Sampaio, S.L., Petropoulos, S.A., Alexopoulos, A., Heleno, S.A., Santos-Buelga, C., Barros, L., & Ferreira, I.C.F.R. (2020), "Potato peels as sources of functional compounds for the food industry: A review", *Trends in Food Science & Technology,* Vol.103, pp. 118-129. doi:https://doi.org/10.1016/j.tifs.2020.07.015

Sandell, M., Laaksonen, O., Jarvinen, R., Rostiala, N., Pohjanheimo, T., Tiitinen, K., & Kallio, H. (2009), "Orosensory profiles and chemical composition of black currant (Ribes nigrum) juice and fractions of press residue", *Journal of Agricultural and Food Chemistry,* Vol.57 No.9, pp. 3718-3728.

Santagata, R., Ripa, M., Genovese, A., & Ulgiati, S. (2021), "Food waste recovery pathways: Challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment", *Journal of Cleaner Production,* Vol.286, pp. 125490. doi:https://doi.org/10.1016/j.jclepro.2020.125490

Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for Business Students* (8 ed.). New York: Pearson Education Limited.

Sayed, M., Hendry, L.C., & Zorzini Bell, M. (2017), "Institutional complexity and sustainable supply chain management practices", *Supply Chain Management: An International Journal,* Vol.22 No.6, pp. 542-563. doi:10.1108/SCM-10-2016-0365

Schieber, A., Stintzing, F.C., & Carle, R. (2001), "By-products of plant food processing as a source of functional compounds—recent developments", *Trends in Food Science & Technology,* Vol.12 No.11, pp. 401-413.

Schut, E., Crielaard, M., & Mesman, M. (2016), "Circular economy in the Dutch construction sector: A perspective for the market and government".

Scott, W.R. (2014). *Institutions and organizations: Ideas, interests, and identities*: Sage publications.

Scott, W.R., Ruef, M., Mendel, P.J., & Caronna, C.A. (2000). *Institutional change and healthcare organizations: From professional dominance to managed care*: University of Chicago Press.

Searchinger, T., Waite, R., Hanson, C., Ranganathan, J., Dumas, P., Matthews, E., & Klirs, C. (2019). *Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. Final report*: WRI.

Sehnem, S., Vazquez-Brust, D., Pereira Susana Carla, F., & Campos Lucila, M.S. (2019), "Circular economy: benefits, impacts and overlapping", *Supply Chain Management: An International Journal,* Vol.24 No.6, pp. 784-804. doi:10.1108/SCM-06-2018-0213

Seuring, S., & Gold, S. (2012), "Conducting content‐analysis based literature reviews in supply chain management", *Supply Chain Management: An International Journal,* Vol.17 No.5, pp. 544-555. doi:10.1108/13598541211258609

Shekdar, A.V. (2009), "Sustainable solid waste management: An integrated approach for Asian countries", *Waste Management,* Vol.29 No.4, pp. 1438-1448.

Sheppard, P., Garcia-Garcia, G., Stone, J., & Rahimifard, S. (2020), "A complete decision-support infrastructure for food waste valorisation", *Journal of Cleaner Production,* Vol.247, pp. 119608. doi:https://doi.org/10.1016/j.jclepro.2019.119608

Silverman, D. (2016). *Qualitative research*: sage.

Silvestre, B.S. (2015), "Sustainable supply chain management in emerging economies: Environmental turbulence, institutional voids and sustainability trajectories", *International Journal of Production Economics,* Vol.167, pp. 156-169. doi:https://doi.org/10.1016/j.ijpe.2015.05.025
Sirkin, T., & Houten, M.t. (1994), "The cascade chain: A theory and tool for achieving resource sustainability with applications for product design", *Resources, Conservation and Recycling,* Vol.10 No.3, pp. 213-276. doi:https://doi.org/10.1016/0921-3449(94)90016-7
Sirkin, T., & ten Houten, M. (1994), "The cascade chain: a theory and tool for achieving resource sustainability with applications for product design", *Resources, conservation and recycling,* Vol.10 No.3, pp. 213-276.
Soriano-Perez, S., Flores-Velez, L., Alonso-Davila, P., Cervantes-Cruz, G., & Arriaga, S. (2012), "Production of lactic acid from cheese whey by batch cultures of Lactobacillus helveticus", *Annals of microbiology,* Vol.62 No.1, pp. 313-317.
Stadelman, W.J. (2000), "Eggs and egg products", *Encyclopedia of food science and technology,* Vol.2, pp. 593-599.
Stahel, W. (2010). *The performance economy*: Springer.
Stake, R.E. (1995). *The art of case study research*: sage.
Stål, H.I., & Corvellec, H. (2018), "A decoupling perspective on circular business model implementation: Illustrations from Swedish apparel", *Journal of Cleaner Production,* Vol.171, pp. 630-643. doi:https://doi.org/10.1016/j.jclepro.2017.09.249
Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013), "A review of the circular economy in China: moving from rhetoric to implementation", *Journal of Cleaner Production,* Vol.42, pp. 215-227. doi:https://doi.org/10.1016/j.jclepro.2012.11.020
Suchman, M.C. (1995), "Managing legitimacy: Strategic and institutional approaches", *Academy of management review,* Vol.20 No.3, pp. 571-610.
Talekar, S., Patti, A.F., Singh, R., Vijayraghavan, R., & Arora, A. (2018), "From waste to wealth: High recovery of nutraceuticals from pomegranate seed waste using a green extraction process", *Industrial Crops and Products,* Vol.112, pp. 790-802.
Teigiserova, D.A., Hamelin, L., & Thomsen, M. (2019), "Review of high-value food waste and food residues biorefineries with focus on unavoidable wastes from processing", *Resources, Conservation and Recycling,* Vol.149, pp. 413-426. doi:10.1016/j.resconrec.2019.05.003
Teigiserova, D.A., Hamelin, L., & Thomsen, M. (2020), "Towards transparent valorization of food surplus, waste and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy", *Science of the Total Environment,* Vol.706, pp. 136033. doi:10.1016/j.scitotenv.2019.136033
Toulmin, S.E. (2003). *The uses of argument*: Cambridge university press.
Circular Economy Promotion Law of the People's Republic of China, (2008).
Thornton, P.H. (2004). *Markets from culture: Institutional logics and organizational decisions in higher education publishing*: Stanford University Press.
Thornton, P.H., & Ocasio, W. (1999), "Institutional logics and the historical contingency of power in organizations: Executive succession in the higher education publishing industry, 1958–1990", *American journal of Sociology,* Vol.105 No.3, pp. 801-843.
Thornton, P.H., & Ocasio, W. (2008), "Institutional logics", *The Sage handbook of organizational institutionalism,* Vol.840, pp. 99-128.
Tranfield, D., Denyer, D., & Smart, P. (2003), "Towards a methodology for developing evidence‐informed management knowledge by means of systematic review", *British journal of management,* Vol.14 No.3, pp. 207-222.
Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S., & Valkokari, P. (2019), "Unlocking circular business: A framework of barriers and drivers", *Journal of Cleaner Production,* Vol.212, pp. 90-98. doi:https://doi.org/10.1016/j.jclepro.2018.11.202
Türkeli, S., Kemp, R., Huang, B., Bleischwitz, R., & McDowall, W. (2018), "Circular economy scientific knowledge in the European Union and China: A bibliometric, network and

survey analysis (2006–2016)", *Journal of Cleaner Production,* Vol.197, pp. 1244-1261. doi:https://doi.org/10.1016/j.jclepro.2018.06.118

Turkulainen, V., Kauppi, K., & Nermes, E. (2017), "Institutional explanations", *International Journal of Operations & Production Management,* Vol.37 No.8, pp. 1117-1140. doi:https://doi.org/10.1108/IJOPM-10-2015-0608

UNEP. (2014). Prevention reduction of food and drink waste in businesses and households—Guidance for governments, local authorities, businesses and other organisations. In.

United Nations. (2017), "World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100", available at: https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html (accessed 10/7/2020)

United Nations Environment Programme. (2021), "Food Waste Index Report 2021", Nairobi,

Upadhyay, A., Laing, T., Kumar, V., & Dora, M. (2021), "Exploring barriers and drivers to the implementation of circular economy practices in the mining industry", *Resources Policy,* Vol.72, pp. 102037. doi:https://doi.org/10.1016/j.resourpol.2021.102037

Urbinati, A., Franzò, S., & Chiaroni, D. (2021), "Enablers and Barriers for Circular Business Models: an empirical analysis in the Italian automotive industry", *Sustainable Production and Consumption,* Vol.27, pp. 551-566. doi:https://doi.org/10.1016/j.spc.2021.01.022

Van Berkel, R., Fujita, T., Hashimoto, S., & Geng, Y. (2009), "Industrial and urban symbiosis in Japan: Analysis of the Eco-Town program 1997–2006", *Journal of Environmental Management,* Vol.90 No.3, pp. 1544-1556.

van Keulen, M., & Kirchherr, J. (2021), "The implementation of the Circular Economy: Barriers and enablers in the coffee value chain", *Journal of Cleaner Production,* Vol.281, pp. 125033. doi:https://doi.org/10.1016/j.jclepro.2020.125033

Vandeginste, V. (2021), "Food waste eggshell valorization through development of new composites: A review", *Sustainable Materials and Technologies,* Vol.29, pp. e00317. doi:https://doi.org/10.1016/j.susmat.2021.e00317

Venkata Mohan, S., Dahiya, S., Amulya, K., Katakojwala, R., & Vanitha, T.K. (2019), "Can circular bioeconomy be fueled by waste biorefineries — A closer look", *Bioresource Technology Reports,* Vol.7, pp. 100277. doi:https://doi.org/10.1016/j.biteb.2019.100277

Venkata Mohan, S., Nikhil, G.N., Chiranjeevi, P., Nagendranatha Reddy, C., Rohit, M.V., Kumar, A.N., & Sarkar, O. (2016), "Waste biorefinery models towards sustainable circular bioeconomy: Critical review and future perspectives", *Bioresource Technology,* Vol.215, pp. 2-12. doi:10.1016/j.biortech.2016.03.130

Vilariño, M.V., Franco, C., & Quarrington, C. (2017), "Food loss and Waste Reduction as an Integral Part of a Circular Economy", *Frontiers in Environmental Science,* Vol.5. doi:10.3389/fenvs.2017.00021

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002), "Case research in operations management", *International journal of operations & production management,* Vol.22 No.2, pp. 195-219. doi:https://doi.org/10.1108/01443570210414329

Wang, X., Chen, Q., & Lü, X. (2014), "Pectin extracted from apple pomace and citrus peel by subcritical water", *Food Hydrocolloids,* Vol.38, pp. 129-137.

Webster, K. (2021), "A Circular Economy Is About the Economy", *Circular Economy and Sustainability,* Vol.1 No.1, pp. 115-126. doi:10.1007/s43615-021-00034-z

Wei, Z., Xu, C., & Li, B. (2009), "Application of waste eggshell as low-cost solid catalyst for biodiesel production", *Bioresource Technology,* Vol.100 No.11, pp. 2883-2885. doi:https://doi.org/10.1016/j.biortech.2008.12.039

Welsh, E. (2002). *Dealing with data: Using NVivo in the qualitative data analysis process.* Paper presented at the Forum qualitative sozialforschung/Forum: qualitative social research.

Wen-qiong, W., Yun-chao, W., Xiao-feng, Z., Rui-xia, G., & Mao-lin, L. (2019), "Whey protein membrane processing methods and membrane fouling mechanism analysis", *Food Chemistry,* Vol.289, pp. 468-481. doi:https://doi.org/10.1016/j.foodchem.2019.03.086

Wernerfelt, B. (1984), "A resource‐based view of the firm", *Strategic management journal,* Vol.5 No.2, pp. 171-180.

Werning, J.P., & Spinler, S. (2020), "Transition to circular economy on firm level: Barrier identification and prioritization along the value chain", *Journal of Cleaner Production,* Vol.245, pp. 118609. doi:https://doi.org/10.1016/j.jclepro.2019.118609

Williamson, O.E. (1981), "The economics of organization: The transaction cost approach", *American journal of sociology,* Vol.87 No.3, pp. 548-577.

Woodside, A.G., & Wilson, E.J. (2003), "Case study research methods for theory building", *Journal of Business & Industrial Marketing*.

WRAP. (2018), "Food waste measurement principles and resources guide" available at: https://ec.europa.eu/food/system/files/2018-04/fw_lib_fwp-guide_food-waste-measurement_wrap-2018.pdf

WRAP. (2020), "Food surplus and waste measurement and reporting guidelines" available at: https://wrap.org.uk/sites/default/files/2020-10/Food-surplus-and-waste-measurement-and-reporting-UK-guidelines.pdf

Xiong, X., Yu, I.K.M., Tsang, D.C.W., Bolan, N.S., Sik Ok, Y., Igalavithana, A.D., Kirkham, M.B., Kim, K.-H., & Vikrant, K. (2019), "Value-added chemicals from food supply chain wastes: State-of-the-art review and future prospects", *Chemical Engineering Journal,* Vol.375, pp. 121983. doi:https://doi.org/10.1016/j.cej.2019.121983

Yang, W., Kortesniemi, M., Ma, X., Zheng, J., & Yang, B. (2019), "Enzymatic acylation of blackcurrant (Ribes nigrum) anthocyanins and evaluation of lipophilic properties and antioxidant capacity of derivatives", *Food Chemistry,* Vol.281, pp. 189-196. doi:https://doi.org/10.1016/j.foodchem.2018.12.111

Yin, R.K. (2013). *Case Study Research: Design and Methods*: SAGE Publications.

Yuan, Z., Bi, J., & Moriguichi, Y. (2006), "The circular economy: A new development strategy in China", *Journal of Industrial Ecology,* Vol.10 No.1 ‐ 2, pp. 4-8.

Zabaniotou, A. (2018), "Redesigning a bioenergy sector in EU in the transition to circular waste-based Bioeconomy-A multidisciplinary review", *Journal of Cleaner Production,* Vol.177, pp. 197-206. doi:https://doi.org/10.1016/j.jclepro.2017.12.172

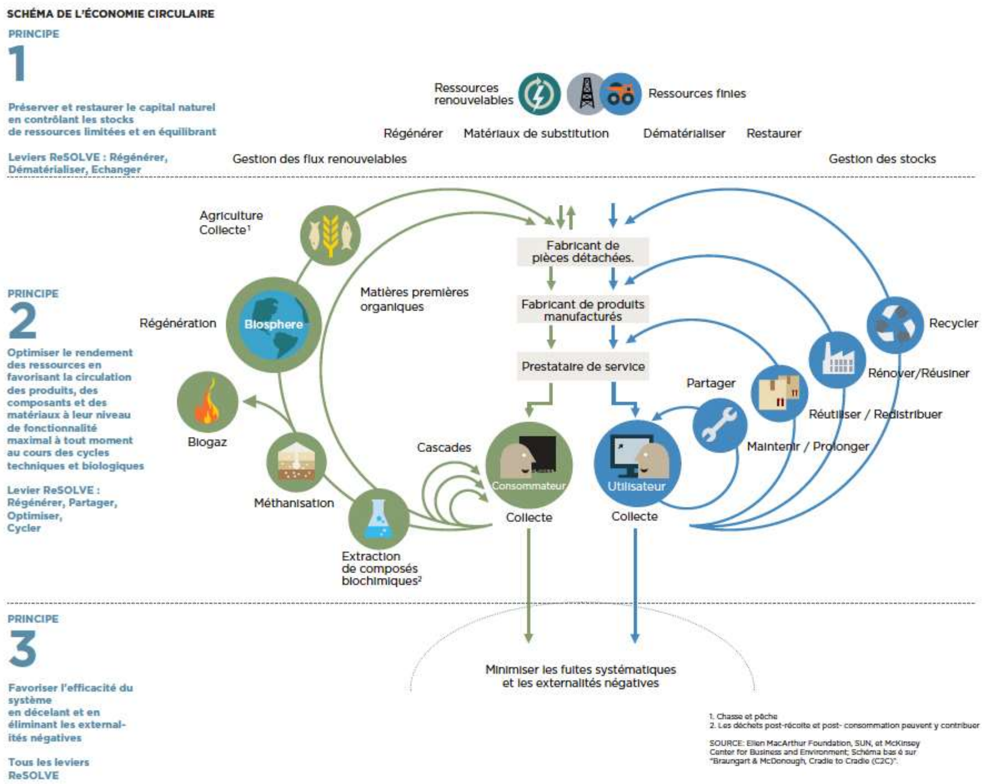
Zabaniotou, A., & Kamaterou, P. (2019), "Food waste valorization advocating Circular Bioeconomy - A critical review of potentialities and perspectives of spent coffee grounds biorefinery", *Journal of Cleaner Production,* Vol.211, pp. 1553-1566. doi:10.1016/j.jclepro.2018.11.230

Zucker, L.G. (1987), "Institutional theories of organization", *Annual review of sociology,* Vol.13 No.1, pp. 443-464.

Zykwinska, A., Boiffard, M.-H.l.n., Kontkanen, H., Buchert, J., Thibault, J.-F.o., & Bonnin, E. (2008), "Extraction of green labeled pectins and pectic oligosaccharides from plant byproducts", *Journal of Agricultural and Food Chemistry,* Vol.56 No.19, pp. 8926-8935.

Appendices

Appendix 1: The butterfly diagram of the circular economy



Source: Ellen MacArthur Foundation (2015, p. 6)

Appendix 2: Example of the information sheet

We would like you to consider participating in a study I am conducting at Hull University, Faculty of Business, Law and Politics. This invitation sheet provides further information about this project and your involvement in the research.

Project title: An investigation into practices and determinants of the circular economy in the food by-product management using multiple case research design

The aim of the project is to draw on the direct perception and experience of the actors who engage in the current state-of-the-art circular practices in the food by-product management in order to grasp a thorough understanding of these practices and the factors that foster and hinder them. The project will focus on getting insights into valorisation technologies and influencing factors from a multi-disciplinary approach.

Participation in this study is voluntary. It will involve a virtual interview of approximately one hour in length to take place in the UK.

The procedures involve interviews.

- You may decline to answer any of the interview questions if you so wish. Furthermore, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher(s).
- With your permission, the interview will be audio/video recorded to facilitate the collection of information and later transcribed for analysis. Shortly after the interview has been completed, we will send you a copy of the transcript to give you an opportunity to confirm the accuracy of our conversation and to add or clarify any points that you wish.
- All information you provide is considered strictly confidential. Your name and your organisation's name will not appear in any thesis or report resulting from this study, however, with your permission anonymous quotations may be used.
- Data collected during this study will be retained for 1 year in a locked office at the University of Hull. Only researchers associated with this project will have access.
- There are no known or anticipated risks to you as a participant in this study.

Should you [the participant] have any concerns about the conduct of this research project, please contact the Secretary, Faculty of Business, Law and Politics Research Ethics Committee, University of Hull, Cottingham Road, Hull, HU6 7RX; Tel No (+44) (0)1482 463536.

We hope that the results of our study will be of benefit to the organisations directly involved in the study, as well as to the broader research community.

We very much look forward to speaking with you and thank you in advance for your assistance in this project.

Yours Sincerely,

Name of Researcher: Quynh Do

Title: PhD Candidate

Email address: N.Q.Do-2016@hull.ac.uk

Appendix 3: Example of the interview protocol

Research title: An investigation into practices and determinants of the circular economy in the food by-product management using multiple case research design

Research purpose: We would like to invite you to participate in a research study in which you will be asked a series of the following questions regarding the circular economy in the management of food processing by-products in the UK.

Research questions during the interview

- *Background information*: Can you please introduce yourself and provide the background of your firm? (Including historical development, number of employees and market share if any). What do you think of the overall landscape for the management of food waste and how does your company fit in this picture?
- *Circular process*: How do you interpret the circular economy and adopt it in your operations? Which type of technologies do you use to convert the food by-products into desirable outputs? How do you configure your supply chain (How do you work with your suppliers and secure relationship with customers and other related parties)? What are your targeted output products? and what types of markets do these products get into?
- *Drivers:* What drives your firm to engage in these innovative circular economy practices? To what extent do these factors influence your decisions to engage in circular practices?
- *Barriers:* When adopting circular practices, what types of barriers challenge your firm's success? What are the most pressing barriers which require industrial attention?

Will my information be confidential and what happens if I want to withdraw?

All information collected about you and your firm will be kept private and confidential. If information about you and your firm is published, it will be in a form such that you and your firm cannot be recognised. Whilst the researcher will keep a copy of all participants' names on the attached consent form, this information will not be kept alongside any data. Your participation in the study is voluntary and you are free to choose whether or not to complete the study. You may withdraw from the procedure for any reason at any point.

Thank you for your time.

Appendix 4: Interview profile and coding

Case ID	Job title of interviewee	Interview ID	Interview duration
A1	Project Manager	A1-1	60 minutes each in August 2020 – April 2021 (teams)
	Project Team Member	A1-2	
	Project consultant	A1-3	
	Operations Manager	A1-4	
A2	Founder and Director	A2-1	60 minutes each in December 2020 – March 2021 (teams)
	R&D staff	A2-2	
	Sales Manager	A2-3	
A3	Founder and Director	A3-1	60 minutes each in March and April 2021 (teams)
	R&D staff	A3-2	
	Sales Manager	A3-3	
	R&D staff	A3-4	
C1	Chief Operating Officer	C1-1	60 minutes each in February and March 2021 (teams)
	Commercial Head	C1-2	
	Managing Director	C1-3	
	Factory Production Manager	C1-4	
	R&D staff	C1-5	
C2	Co-founder & Chief Marketing Officer	C2-1	45-60 minutes in June – July 2021 (teams)
	Co-founder & Chief Executive Officerr	C2-2	
	Polymer Chemist (R&D)	C2-3	
	Bioechnologist (R&D)	C2-4	
C3	Founder and CEO	C3-1	30-90 minutes each in May – September 2021 (teams)
	Sustainability and Research Manager	C3-2	
	Head of Sales and Business Development	C3-3	
	Sales staff	C3-4	

Appendix 5: Example of interview transcripts

Can you please introduce yourself and provide the background of your firm? (including historical development, number of employees, production capacity and market share, if possible)?
My company was founded in 2013 by an architecture student at [*a leading UK University*]. The founder was tasked with looking at the coffee shop and making it more sustainable. The founder, very clever, took a bag of coffee grounds into the labs at [*a leading UK University*]. and said, What can we do with these? What is in spent coffee grounds? How do we valorise this waste product? So that was the kind of the sort of lightbulb moment behind your story. So really from 2013 to 2016, was when we first started really selling products. And the ride has been quite bumpy. Up until sort of, you know, 2017, 2018, 2019 was when we really had, you know, some large coffee log customers. So actually, we knew that we could process a lot of the grounds we were getting in, but we still are building our raw material supply chain of spent coffee grounds. And again, it's not, it's not easy, because we've got to build models on what we think we can sell, what we can turn the product into. There's lots of new product development, we are talking to people that could come on board. And at the moment, if we process about seven and a half thousand tonnes, we're talking to companies that might be able to increase that volume by another 10,000 tonnes. So we've got this constant juggling act between feedstock and the amount of coffee grounds coming in. And, and so we can wait. If we build too much demand for the product, we probably won't have enough feedstock. If we don't build enough demand for them, we can have too much. So yeah, it's quite a complex model. At the moment, we have 35 staff and occasionally in busy times, such as when winter hits or Christmas or BBQ season, we hire some agency staff. They aim to keep a baseline production all year round and additional production using seasonal staff.
What do you think of the overall UK landscape for food waste management? how does your company fit in this picture?
What we're trying to address is the fact that we think there are about 500,000 tonnes of spent coffee grounds in the UK, which prior to us and other disposal routes, a lot of those coffee grounds were ending up in landfills, which is bad. This is bad for the environment because they release methane. It's also a waste because you're not valorising you know, a waste stream that can be used in other things. Probably the least bad method is then it goes to anaerobic digestion. Unfortunately, the people who run the AD plant don't necessarily like coffees in any large volumes. In some of the cafes we talk to, we are 50% of their waste so if you're collecting your anaerobic site, and you're collecting the food from coffee shops, you're

getting a lot of coffee. They do not work very well in anaerobic digestion. So yeah, the worst case, it goes to landfill otherwise, you know, the general way burnt, they don't capture the value, or it goes to anaerobic. I think we are experienced has been the way the country has been set up in the way that systems and stuff in the country work is that anaerobic digestion has been given reuse or primacy, I guess. That's been, I think, that's been quite heavily subsidised as a route to sort of take up large volumes of by-products, food waste. And so and that is there for kind of almost the default scene as just the acceptable good place in which food waste can go to. And so, we that then seems to miss some of the nuances, you know, so some of the, you know, it doesn't, it hasn't really engaged with opportunities with feedstocks to do more.
How do you interpret the circular economy and adopt it in your operations?
Well, broadly, I suppose, we've turned your waste material into a product that can be reused. So that's sort of a very high level of the circular economy. Ideally, the product would not be a single-use product so I think it's turned into a more permanent product, a multi-use product. And then that would be ideal. And in line with sort of circular economy thinking, you know, we should be extending the life of all products and we can. And I suppose the second ideal piece as well. If that product is somehow returned to the industry or sector that it emerged from. So, you know, it's from the coffee sector. So it was very attractive early on to see whether the coffee pellets could be used by roasters for their energy needs. So that sort of circularity piece there I think so using it back in the same industry would be preferable.
Which type of technologies do you use to convert the by-products into desirable outputs? What is the TRL level of the technology?
we there's certain proprietary technology that we have. But the basic model is coffee comes into us and it's either from the retail sector or the instant coffee. That coffee is 60 cents moisture. When we want to make our materials or when make our further products, we need that material to be down to about 10% moisture. So the biggest part of our process is taking the coffee in and if you imagine the coffee that comes from the retail sector, so that's the coffee shops, you know, try as we do to get the coffee as cleanly as possible. It has contamination, so we have to decontaminate the coffee, and that could be contamination is the bags that arrive in any, you know, might be the occasional banana skin or coffee cart or whatever. So our first job is to decontaminate it, we then need to dry it. So we've got a biomass dryer. So we're able to try with a carbon-neutral fuel because you need the energy to dry the coffee. So when I arrived at by being, we weren't, we didn't have a biomass dryer, and it was one of our, you know, one of the pilot factory, it would be very expensive to start

with a biomass boiler, we needed to prove the concept before introducing a carbon-neutral means of drying that spent coffee grounds. So yeah, so then we dry the spent coffee grounds down to 10%. And that gives us our raw, sort of refined, decontaminated, dried material. And then we decide whether that goes into our coffee logs, into our coffee pellets, into just dry grounds for further processing into bioplastics, or brake pads, or wherever. You know coffee is 70% wet, it's also 14% oil, it's viscous sticky.
How do you configure your supply chain? How do you connect to suppliers and customers and other parties of concerns such as transportation firms or waste management services?
we will have a slightly strange business model in the fact that we almost had to set up two supply chains: supply in and supply out because you can't just go to market and buy spent coffee grounds as an ingredient. So we had to partner with or persuade people to partner with us in giving us their spend ground, or us processing their spent grounds. And then also at the same time, setting up a supply chain out, because it's all very well getting lots of coffee into the factory. But if you don't process it, turn it into a product, or material that people want, then you just end up with a mountain of coffee.
What are your targeted output products?
The products we make coffee logs, coffee pellets, and we also extract some of the flavours and fragrances, which is we call the FNF flavours and fragrances there are the three products we own. But then we also have the raw material, which we're working with third parties to turn that into various bio-plastics and other brake pads and many other uses. We're doing a lot with bio-plastics at the moment. So our hope is that for example, Costa or McDonald's will use plastics in their shops that have been made using coffee. So I think there's a circularity whereby the sector itself is circular rather than you take it out one sector and put it into another one. I think that would be preferable. I think, how we apply it is that we’re investing in R&D, and trying to develop new products that hit our definition of circular economy, you know, permanent reuse in the same sector. So that's that thinking which one applies a lot and keep striving for those higher-grade products. And I think the drivers of the success, whether we'll be successful or not, is taking care of the products we've got really, you know. McDonald's probably buy 1000s of tonnes worth of plastic products a year. Yeah, so they could if they wanted to specify that they're all made from, you know, 1000s of tonnes of those are made using by-products from their food

process….. So that's helping to enable us to develop as a business. Because we're starting to knock on more open doors now like they are okay how can we reuse it, how can we reuse it let us work with you to see. So they are starting to become a customer product, so I think that is helping nothing as quite a bit. A driver was that inherent value in coffee grounds was not being utilised. I think there's an inherent value because it wasn't being utilised. I think it was a belief that coffee grounds is such a sort of trendy premium product, as it is, I think it was a belief that coffee is a bit of a sexy waste stream that people would be interested in and would want to work in it and that it would work well as a circular product. We were not as bad as chicken feathers or that sort of stuff because of that consumer position.
What types of markets do these products get into?
What dictates where I put in the commercial value. If somebody's gonna start paying me lots of money to sell material, we don't have to make bolts or collect. I'm not ready to make pallets. We have established the market. Yeah, so it's, that's when you start doing interesting is when we decide what we start with, where is the best value, but as I said if there are 5000 tonnes of SGC in the UK, there won't be an issue of me having to decide where it goes, it's just given me some more coffee. They process about 7,500 tons; the majority of their inputs goes into the solid fuels business or the bioplastic. Don't use all of the material for extracting the flavours and fragrances. We just use a very small proportion at the moment. But what we do is we decontaminate, we dry decontaminate again because it's much easier to work with a dry material to decontaminate again. And then we can make the decision whether the material goes to be distilled to get the flavours and fragrances. so we sell into B&Q, Wicks, Waitrose Morrison, you know, the big DIY turnings. And so our end customer is something that would burn somebody with a solar heating appliance in their house user, our customers, the big supermarket chains and big garden centres. Online, Amazon, eBay, there are lots of places for the pallets we typically sell to we've got one or two customers. For example, one of the customers he makes uses a lot of steam in its process boy says he uses the powers of boilers, but another guy, he grows crops for supermarkets in greenhouses. So he has acres and acres of glasshouses and he needs to heat those plants. So, he actually used his greenhouses we should get our economy stored because we can take coffee from them to turn it into the fuel they can in to create the heat

What drives your firm to engage in these innovative circular economy practices? **To what extent do these factors influence your decisions to engage in circular practices?**
There is a bigger drive to sustainability within public consciousness. I'm hoping that there is more and more, there is a better case for valorising to those that would otherwise have gone to waste. And I think a lot of that by design procedure for waste. Whether those are sort of targeted around tax. We've got plastic tax coming into things like the plastic tax is quite interesting. Because suddenly, all the plastic manufacturers are going to be forced to be using, you know, 30% no less than 30%. Recycled renewable material in their plastic, otherwise they get charged 200 pounds per tonne. So, that may be a good driver to look at our spent coffee grounds to use as a filler in various bioplastics. In the same way, I think landfill tax is expensive. If you can actually find going somewhat you have some of the big chains we work with sending multiple 1000s of times. A huge expense, it's very much in their interest to look at dealing with their way solving it needs to be consumer-led government-led and business. I think it was a belief that coffee grounds is such a sort of trendy premium product, as it is, I think it was a belief that coffee is a bit of a sexy waste stream that people would be interested in and would want to work in it and that it would work well as a circular product. We were not as bad as chicken feathers or that sort of stuff because of that consumer position.
What types of barriers or challenges do you perceive throughout your adoption process?
The big challenge is to persuade providers of coffee to give you their coffee, and we've done that through the sustainability argument. To look at CO_2 is the way we tried to sort of making the case to McDonald, Costa, Starbucks, whoever, this is why it's better for you to send your coffee weights to us than it is to just put it in with everything else. So like I say, we've done it using Carbon footprint analysis, lifecycle analysis on our process, then comparing it to those coming from different sources. Also, getting people and the coffee shops to provide us coffee is a segregated waste stream and to not just throw it in with their food waste is, is kind of is an ongoing challenge for the business because we need to give them the incentives and the rationale, and the reason to want to go and do that. And we found that part. So regulations surrounding manufacturing, processing the product itself only needs to be rules and regulations governing especially things like waste, people like ourselves who are trying to extend the life, materials, unfortunately, get caught up in a lot of bureaucracy to

shame. I guess when you're doing something new. When you are pioneers. A lot of the existing rules and regulations are not fit for purpose, but one example of that. The burning of coffee logs, where we're not cold. We're not worried. We're somewhere between. While we're biomass, all of the regular around, wood, coal, it is understandable because that was so we now bring in something new and novel and dangerous don't know what to do with it, then they try, but we represent a very small bit of the market. We're dealing with government departments gonna be quite busy with Brexit and everything else. So it's very difficult to try and I think as a, as a small gear, we're not super well on it but we have had investment without spending a lot of money on investing, engaging with debt for the EIA, the government bodies, we would we wouldn't be so that is a real, I think it's, it's an issue in the UK around innovation, if, if the government, truly, innovation, a lot of barriers, need to be expected.