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DEVELOPING BUSINESS MODELS FOR A CIRCULAR BIOECONOMY: THE B2CIRCLE TOOL

DOCTORAL DISSERTATION

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2021

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Desenvolvendo Modelos de Negócio para a Bioeconomia Circular: A Ferramenta B2Circle

Doctoral Dissertation presented as a hurdle requirement to obtain the title of Doctor of Industrial Engineering at the Graduate Program in Industrial Engineering of the Universidade Tecnológica Federal do Paraná (UTFPR).

Supervisor: Prof. PhD. Antonio Carlos de Francisco.

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RODRIGO SALVADOR

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Trabalho de pesquisa de doutorado apresentado como requisito para obtenção do título de Doutor Em Engenharia De Produção da Universidade Tecnológica Federal do Paraná (UTFPR). Área de concentração: Gestão Industrial.

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To the sweetest (but also very stubborn)
person who has ever walked the earth,
mom.

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You miss 100% of the shots
you do not take
(GRETZKY, [19--?])

ABSTRACT

SALVADOR, Rodrigo. **Developing Business Models for a Circular Bioeconomy**: The B2Circle Tool. 2021. 200 pages. Dissertation (Doctor of Industrial Engineering) - Universidade Tecnológica Federal do Paraná (UTFPR). Ponta Grossa, 2021.

Background. The circular bioeconomy (CBE) is a solution to the current linear (take-make-use-dispose) state of many businesses and the increasing generation of waste. In a CBE, biological resources are used to make products of high added value using more circular practises, which products might be novel or serve to replace those currently made from non-renewable sources. Nonetheless, CBE systems need well-designed business models to succeed. Purpose. The objective of this dissertation was to develop a self-assessment tool to assist bioeconomy businesses in adopting and taking advantage of a more circular conduct by suggesting a business model to be pursued. Novelty. The novelty of the present dissertation lies in identifying business models for a circular bioeconomy (BMCBE) and proposing a tool to recommend a BMCBE to bioeconomy businesses. Design/methodology/approach. This research was structured in three Phases. In Phase I, a systematic literature review and a practise review using semi structured interviews were conducted to identify the barriers, challenges, drivers, and opportunities for businesses in a CBE, and to propose a taxonomy for BMCBEs. In Phase II a Delphi study, using Fuzzy Analytic Hierarchy Process (FAHP), assisted by specialists from both academia and industry allowed to validate a set of criteria to determine the characteristics of the BMCBEs and use those criteria to profile the BMCBEs in the proposed taxonomy. A method using the theory of Euclidean distance was also proposed to enable comparing the characteristics of the business model of an organisation that uses the tool with those of the seven BMCBEs. Phase III comprised the testing of the proposed tool. Findings. The proposed taxonomy included seven BMCBEs: Optimising resource efficiency and use; Establishing biorefineries; Value recovery from waste; Resource exchange; Innovation towards bio- and renewable resources; Valuing the local economy, and; Service- and result-oriented offers. A set of 19 criteria were used to profile the seven BMCBEs, and the results of such profiling composed the basis of the proposed tool, named B2Circle. Organisation X was invited to be first user of the tool, to whom the tool recommended the BMCBE “Establishing biorefineries”. This has been validated with Organisation X and opportunities to further develop their business model were discussed. Research implications. The B2Circle tool aims to point a path that can bridge the gap between the current state and the recommended circular business model for an organisation. It is intended as a first step towards greater circularity in bioeconomy businesses, enlightening businesses towards establishing a CBE while accounting for their business approach.

Keywords: business model; circular economy; bioeconomy; circular bioeconomy; circular business model.

RESUMO

SALVADOR, Rodrigo. **Desenvolvendo Modelos de Negócio para a Bioeconomia Circular**: A Ferramenta B2Circle. 2021. 200 folhas. Tese (Doutorado em Engenharia de Produção) - Universidade Tecnológica Federal do Paraná. Ponta Grossa, 2021.

Contextualização. A bioeconomia circular (BEC) é uma solução para o atual estado linear (pegar-fazer-usar-descartar) de muitos negócios e a crescente geração de resíduos. Em uma BEC, recursos biológicos são utilizados para fazer produtos de alto valor agregado utilizando práticas mais circulares, e tais produtos podem ser novos/inéditos ou substituírem aqueles atualmente feitos a patir de fontes não-renováveis. Contudo, sistemas de BEC precisam de modelos de negócios bem delineados para terem sucesso. Objetivo. O objetivo desta tese foi desenvolver uma ferramenta de autoavaliação para auxiliar as empresas da bioeconomia a adotar e desfrutar de uma conduta mais circular, sugerindo um modelo de negócio a ser buscado. Novidade. O aspecto inédito desta dissertação está em identificar modelos de negócio para uma bioeconomia circular (MNBEC) e propor uma ferramenta para recomendar um MNBEC para organizações da bioeconomia. Design/metodologia/abordagem. Esta pesquisa foi estruturada em três Fases. Na Fase I uma revisão sistemática da literatura e uma revisão da prática, utilizando entrevistas semiestruturadas, foram realizadas para identificar as barreiras, desafios, motivadores e oportunidades para negócios em uma BEC, e para propor uma taxonomia para MNBECs. Na Fase II um estudo Delphi, utilizando *Fuzzy Analytic Hierarchy Process* (FAHP), auxiliado por especialistas da academia e da indústria, permitiu validar um conjunto de critérios para determinar as características dos MNBECs e usar esses critérios para traçar o perfil dos MNBECs presentes na taxonomia proposta. Foi também proposto um método utilizando a teoria da distância Euclidiana para permitir comparar as características do modelo de negócio de uma organização que utilizar a ferramenta com as dos sete MNBECs. A Fase III consistiu no teste da ferramenta proposta. Resultados. A taxonomia proposta incluiu sete MNBECs: Otimizando a eficiência e uso de recursos; Estabelecimento de biorrefinarias; Recuperação de valor a partir de resíduos; Troca de recursos; Inovação em direção a recursos biológicos e renováveis; Valorizar a economia local, e; Ofertas orientadas a serviços e resultados. Um conjunto de 19 critérios foi utilizado para traçar o perfil dos sete MNBECs, e os resultados dessa análise compuseram a base da ferramenta proposta, denominada B2Circle. A Organização X foi convidada a ser a primeira usuária da ferramenta, a quem a ferramenta recomendou o MNBEC “Estabelecimento de biorrefinarias”. Isto foi validado com a Organização X e oportunidades para desenvolver ainda mais seu modelo de negócio foram discutidas. Implicações de pesquisa. A ferramenta B2Circle visa apontar um caminho que pode preencher a lacuna entre o estado atual e o MNBEC recomendado para uma organização. A ferramenta tem o intuito de ser um primeiro passo para maior circularidade em negócios da bioeconomia, dando direção no sentido de estabelecer uma BEC ao mesmo tempo que considera a sua abordagem de negócios.

Palavras-chave: modelo de negócio; economia circular; bioeconomia; bioeconomia circular; modelo de negócio circular.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

AHP	Analytical Hierarchy Process
BBIJU	Bio-based Industries Joint Undertaking
BE	Bioeconomy
BM	Business Model
BECE	Backcasting and Eco-design for the Circular Economy
BMCBE	Business Model for a Circular Bioeconomy
BSI	British Standards Institute
B2B	Business-to-business
B2C	Business-to-consumer
$CaCO_3$	Calcium Carbonate
CAPES	*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*
CBE	Circular Bioeconomy
CBM	Circular Business Model
CE	Circular Economy
CFC	Chlorofluorocarbon
CR	Consistency Ratio
DU	Declared Unit
ECLAC	Economic Commission for Latin America and the Caribbean
EPD	Environmental Product Declaration
FAHP	Fuzzy Analytical Hierarchy Process
FU	Functional Unit
GDP	Gross Domestic Product
GPI	Genuine Progress Indicator
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LESP	Sustainable Production Systems Laboratory
MCDA	Multi-criteria Decision Analysis
MF	Membership Function

MSW	Municipal Solid Waste
OR	Other Relevance
PPGEP	*Programa de Pós-Graduação em Engenharia de Produção*
PR	Practise Review
PSS	Product-service System
R&D	Research and Development
SDG	Sustainable Development Goal
SLR	Systematic Literature Review
ST	Search String
TBS	Take-back System
TFN	Triangular Fuzzy Number
UTFPR	*Universidade Tecnológica Federal do Paraná*
WBCSD	World Business Council for Sustainable Development

INDEX

1 INTRODUCTION

A rampant consumption of resources has been raising societal awareness towards a more sustainable production and consumption. It is believed that society consumes materials at a rate of 1.5 times what the planet can bear (JANSSEN; STEL, 2017). Thus, the current pace at which natural resources are being consumed might lead to ecological collapse (GREGORIO *et al*., 2018). Even more because on top of said resource consumption, society produces large amounts of waste (MAINA *et al*., 2017). Designing out all that waste (BSI, 2017) could help reduce both the environmental impacts and economic concerns (PRASAD, 2015) associated with it, by generating less disposable waste (e.g., resources used inefficiently, and money lost with unused materials and products simply thrown away). A solution is offered by the circular economy (CE) (GEISSDOERFER *et al*., 2017), which claims that society's activities should use nature as example and make all processes circular (EMF, 2013), there being no waste to be disposed of, with all outputs being inputs to other processes (SCHULTE, 2013).

Nonetheless, a CE on its own cannot be said to be completely environmentally sustainable (SALVADOR *et al*., 2020) and might still make use of non-renewable, fossil resources. The bioeconomy (BE) then emerges, encouraging the transition to an economy based on renewable, bio-based resources (DAHIYA *et al*., 2018). However, a BE still needs to be circular and resemble natural processes, for excessive use and lack of care with the harvest and obtention of biomass can often lead to land degradation and land-use change, loss of biodiversity, climate change, and water pollution (MUSCAT *et al*., 2021), thus the establishment of a circular bioeconomy (CBE) is of great relevance towards a more sustainable development. A CBE can be translated into a set of strategies that help advance the biological flows of a CE and is characterised by the use of biomass as a resource, with a cascaded use in a continued recirculation of materials, seeking an optimal use of resources (SALVADOR *et al*., 2021b). Therefore, it is observed that one way to meet the need for an economy that does not exceed the biophysical limits of our planet is the establishment of a CBE (MUSCAT *et al*., 2021).

Moreover, a CBE provides for adaptation and evolution of organisms and ecosystems in a changing environment, while still allowing humans to benefit from biological resources and ecosystem services (PALAHÍ *et al*., 2020), seen that biodiversity has been declining faster than at any other time in history, and approximately 1 million species risk extinction (IPBES, 2019). It also helps rethink food systems, responsible for 21-37% of global greenhouse gas (GHG) emissions (IPCC, 2020), and could help reduce deforestation, which alone is responsible for 25% of the emissions from food production (PALAHÍ *et al*., 2020). In addition, it enables transforming the land sector to mitigate impacts and reach the 1.5°C target by 2050 (ROE *et al*., 2019). This can be done by scaling up more sustainable practises in agriculture and marine management systems (e.g., such as seaweed cultivation, as well as forestry measures which are climate smart) (VERKERK *et al*., 2020).

Furthermore, a CBE can transform industrial sectors, who are responsible for another 30% of global GHG emissions, of which the majority originates from bulk (non-renewable) materials such as chemicals and petrochemicals, cement, and metals (WESSELING *et al*., 2017). This can be done by developing innovations that are scalable and make use of viable technologies, resulting in biobased low-carbon products based on circular businesses, optimising efficiency of resources by (re)circulating materials, components, and products in both technical and biological cycles (PALAHÍ *et al*., 2020).

A CBE can also help meet the increasing energy demand by society for the maintenance of wellbeing and productivity (RAUGEI *et al*., 2020) through the use of biological and renewable sources, as renewable sources have greater potential than non-renewable ones (INTERNATIONAL ENERGY AGENCY, 2015), while decarbonizing the energy sector (BOUDET *et al*., 2021), contributing to achieve a carbon neutral economy (LANGSDORF, 2011). This can be done by investing in the many renewable sources of energy, ranging from solar (through thermal, photo-chemical, and photo-electric means), to biomass, hydropower, wind, geothermal, and tidal power (AZAM *et al*., 2021).

The transition towards greater environmental sustainability, nevertheless, affects businesses, making them reconsider their strategies and business models (BM) (NÄYHÄ, 2020). Hence, the establishment of a CBE calls for BM innovation (HANSEN, 2016) and poses the need to adapt to changing business environments (NÄYHÄ, 2020).

Nonetheless, there is a lack of approaches of CE from a business perspective (GREGORIO *et al*., 2018), and research or practise on circular business models (CBM) (BOCKEN *et al*., 2017) for the BE (REIM *et al*., 2017) is still scarce. What is more, what there is on the discussion of business models for a circular bioeconomy (BMCBE) is fragmented and lacks a research agenda, making the benefits and insights on BMCBEs not fully mapped out (REIM *et al*., 2017) or completely understood yet. Therefore, businesses need guidance on how to transition to a CBE and take better advantage of the opportunities linked to their type of business, acquiring knowledge of the opportunities linked to their business approach within the BE environment.

Considering the aforementioned, this dissertation seeks to answer the following research question: *How could bioeconomy businesses become more circular while taking better advantage of opportunities in a bioeconomy by developing adequate business models?*

1.1 OBJECTIVES

1.1.1 General Objective

The general objective of this research is to develop a self-assessment tool to assist bioeconomy businesses in adopting and taking advantage of a more circular conduct by suggesting a business model to be pursued.

1.1.2 Specific Objectives

i. Identify the barriers, challenges, drivers, and opportunities for businesses in a circular bioeconomy;
ii. Identify overarching business models for a circular bioeconomy;
iii. Define criteria to profile and to set apart the overarching business models for a circular bioeconomy identified in ii;
iv. Propose a method to assess the overarching business models for a circular bioeconomy identified in ii and the (existing or desired) business model of an organisation using the tool;

v. Propose a method to recommend which overarching business model for a circular bioeconomy best fits an organisation using the tool;
vi. Select an organisation to test the tool;
vii. Use the tool to recommend a business model to the selected organisation;
viii. Conduct an analysis of the selected organisation (and its product system) to make specific recommendations for improved circularity based on the recommended business model.

Having presented the objectives of this dissertation, the next section outlines the main reasons to conduct this research.

1.2 JUSTIFICATION AND CONTRIBUTIONS

With the increase of convenience provided by technological developments, society has been producing increasing amounts of waste. Organisations take resources from nature, use them to make the desired products, consumers use those products and what is left of them is simply thrown back at nature. Many times, those resources at their “end-of-life” do not resemble the original form in which they were when extracted. In a search to avoid such extensive generation of waste, the concept of CE has been gaining prominence. In a CE, systems are regenerative by nature and strategies that seek to slow, narrow, and close flows of resources are deployed in order to make resources stay within technical cycles (i.e., in use by humans) for longer before being given back to the environment.

Nonetheless, considering that a CE by itself might not be entirely sustainable, and that it is not necessarily based on renewable resources, the increasing need for materials and energy has been forcing society to transition from the linear consumption of fossil resources to renewable/biological ones in a circular approach (DAHIYA *et al.*, 2018). Therefore, some advocate for a CBE. A CBE uses bioresources to make products of high added-value and establish cascaded systems to make the best use of those resources, making them go on as many cycles as possible, and when they are finally returned to the environment, they are as harmless as possible to nature.

Moreover, given the existing high rate of waste generation and an economic benefit due to potential valorisation, in a CBE waste recovery also contributes to preventing pollution (PRASAD, 2015). Generation of organic or biological waste is an environmental issue in many places (e.g., food and industrial waste), thus, converting such waste into value-added, marketable products (KWAN *et al*., 2018), might enable addressing both environmental and economic concerns (MOHAN *et al*., 2018).

Nevertheless, to accelerate the implementation of a CBE, it is important to find ways to couple those environmentally friendly actions with economic feasibility. On those grounds, it is believed that a CBE unveils opportunities that might reach the figure of 7.7 trillion US$ until 2030 (WBCSD, 2019). Therefore, designing new BMs (one of the buildings blocks of a CE) for a CBE and adapting the existing ones is of utmost importance for this transition to occur.

On those grounds, having a tool that helps directing efforts towards greater circularity is of singular relevance where practical guidance is needed (URBINATI *et al*., 2017). In addition, as companies may fight disregarding business needs and desires at the expense of greater circularity, there is a need to couple such interests in a harmonious way. Stemming from the aforementioned, this research expresses its relevance and contribution on the academic, operational, organisational, technological, and social aspects as presented hereafter.

The academic relevance of this research lies on its very novelty and originality, as to the best of the author’s knowledge, there seems to be no tools or methods tailored to help develop BMCBEs thus far. Existing tools help develop businesses from the perspective of technical cycles (as per the butterfly diagram from the Ellen Macarthur Foundation - EMF) (refer to Figure 2, page 27) such as Circulytics (EMF, 2021a), by measuring business circularity, and the expert system for circular economy business modelling developed by Pieroni *et al*. (2021), by advising manufacturing companies in decoupling value creation from resource consumption. On the BE realm, though, the greatest efforts have been observed towards the forestry sector (DAHIYA *et al*., 2018; D'AMATO *et al*., 2020; JARRE *et al*., 2020; NÄYHÄ, 2020) and the value recovery from agricultural waste (DONNER; RADIC, 2021; DONNER; VRIES, 2021; DONNER *et al*., 2020; DONNER *et al*., 2021); however, no study resembling this dissertation’s approach was found, i.e., defining overarching BMCBEs and proposing a method to suggest the most suitable BMCBE for an organisation within the BE context to pursue in order to embark on a circular (or more circular) path.

The operational relevance is outlined by the guidance to be offered to businesses using the proposed tool, showing them a path to benefit from the opportunities regarding BMCBEs related to their business interests. Such paths (i.e., BMs) will assist businesses towards breaking down strategies into operational tasks to achieve a desired performance.

The organisational relevance is highlighted by the opportunity for businesses to couple more environmentally sustainable strategies (addressing a CBE approach) into their businesses on a win-win-win (business, environment, and society) perspective.

The technological relevance lies in the potential to enlighten businesses to pursue technological routes that aid further technological advancement towards a cleaner, more responsible and circular production (either by designing new technologies or redesigning existing ones). That helps to reduce the dependency on the speed of natural cycles (e.g., technologies for carbon capture and storage, and plants with improved photosynthesis) (MUSCAT *et al*., 2021).

The social relevance is given by the behaviour fomented by CBE systems, which are rooted in more renewable resources. This enables greater social wellbeing in the long-term (PALAHÍ *et al*., 2020) and helps shape social behaviour by increasing awareness (e.g., the role of “psychological distance” bias in MUSCAT *et al*., 2021). On top of that, the social contribution also lies in the potential practical use of the proposed tool, where companies can use the tool to investigate strategies towards greater circularity, and it can inspire governments to establish public policies towards incentivising and supporting BE businesses. Nonetheless, although the contribution to and influence of the social dimension in this research are inherent and undeniable, the analysis of the social aspects is not part of the scope of this dissertation, thus they are not assessed or addressed in detail.

Moreover, the proposed tool aims to be a starting point for organisations to think critically about their BM and design more circular businesses. Organisations using the tool will be presented with the BMCBE that best fits their business and will gain (see on page 23):

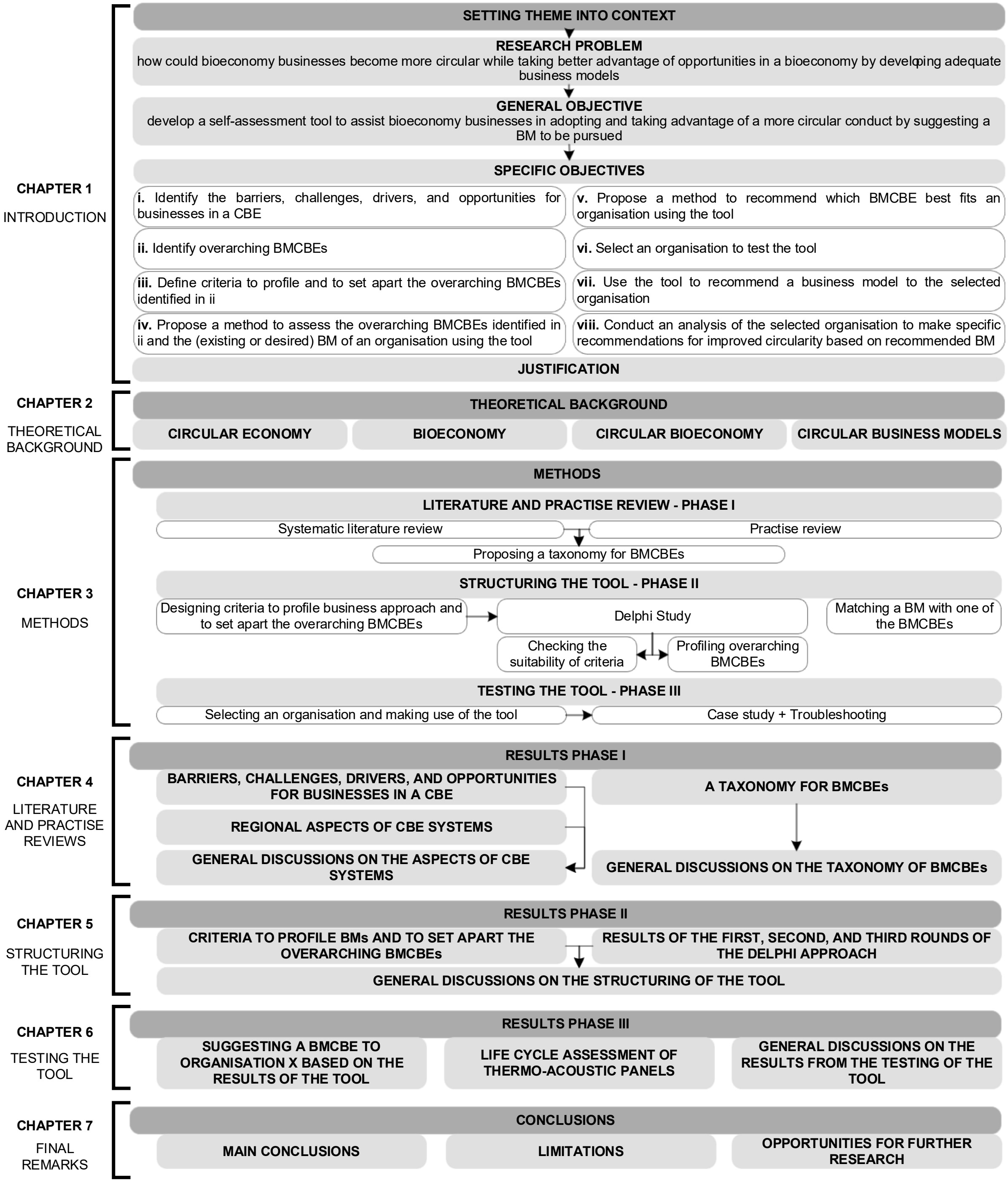
- Access to the characteristics of the suggested BMCBE, which they can analyse and compare to their current or desired vision of a future BM;
- Insights based on the example strategies provided along with the BMCBE presented to them;
- The opportunity to design novel strategies or adapt existing strategies to achieve the suggested BMCBE;
- Insights on value-adding possibilities based on the BMCBE proposed.

Having outlined the relevance of the present dissertation, the next section presents its structure.

1.3 STRUCTURE OF DISSERTATION

This section aims to present the overall structure of this dissertation, showing what the reader can expect from each of the Chapters in it. Figure 1 (page 24) summarises the main content in each Chapter. Chapter 1 presents the initial considerations on the main subjects dealt with in this dissertation, outlining the objective of this research and the reasons for conducting it. Chapter 2 lays the theoretical background that supports and justifies the development of the proposed tool. Chapter 3 presents the methods used in this dissertation, encompassing the methods for the systematic literature review and the practise review, as well as the methods for building and testing the proposed tool. Chapter 4 shows the results from Phase I of this research, thus the systematic literature review and the practise review, including the barriers, challenges, drivers, and opportunities for a CBE (overall and in different continents) and the proposed taxonomy for BMCBEs. Chapter 5 presents the results from Phase II, thus the criteria to define the characteristics of the proposed BMCBEs and the Delphi study to profile them. Chapter 6 presents the results of Phase III, thus the testing of the proposed tool. Finally, Chapter 7 draws on the final remarks of this research.

Figure 1 - Structure of dissertation



BM – Business Model
BMCBE – Business Model for a Circular Bioeconomy
CBE – Circular Bioeconomy

Source: Author (2021)

As seen in Figure 1, the next Chapter presents the theoretical background, which aids a better understanding of the subjects addressed in this dissertation.

2 THEORETICAL BACKGROUND

This chapter aims to present a brief theoretical background to aid understanding of the topics of interest to this dissertation. The chapter covers an introduction on circular economy (section 2.1) and its importance to a more sustainable development, followed by the concept of bioeconomy (section 2.2) and the transition to renewable bio-based resources, leading to a circular bioeconomy (section 2.3), where the CE and BE concepts overlap. Next, the idea of business models is presented, and their importance to an economically feasible CE by means of circular business models (section 2.4) is outlined. The intertwining of all these concepts finally lead to an understanding of the need to prepare a CBE aided by adequate BMs, which entails the results and discussions presented in Chapters 4, 5, and 6. Moreover, the main references used in each topic in the theoretical background are presented in Table 1.

Table 1 - Main references for the theoretical background

Theoretical Background Topic	Main References
2.1 Circular Economy (CE)	Benyus (1997); Boulding (1966); BSI (2017); Commoner (1971); EMF (2013); Graedel and Allenby (1995); Lovins *et al*. (1999); Lyle (1996); McDonough and Braungart (2002); Pauli (2010); Pearce and Turner (1990); Stahel (2010); WBCSD (2017)
2.2 Bioeconomy (BE)	D'Amato *et al*. (2017); Enriquez (1998); European Commission (2018); Näyhä (2019); Paredes-Sánchez *et al*. (2019)
2.3 Circular Bioeconomy (CBE)	D'Amato *et al*. (2020); Muscat *et al*., (2021); Prasad (2015); Reim *et al*. (2019); WBCSD (2019)
2.4 Circular Business Models (CBM)	Bocken *et al*. (2017); CIRCULAB (2021); Lewandowski (2016); Nussholz (2018); Osterwalder and Pigneur (2010); Pieroni *et al*. (2018)

Source: Author (2021)

Given the main sources of knowledge used to structure the initial basis of this research, the theoretical background is presented hereafter.

2.1 CIRCULAR ECONOMY (CE)

A CE is a system based on material or energy inputs and outputs conceived to be restorative or regenerative, by replacing the concept of ‘end-of-life’ with restoration, i.e., making use of renewable energy, eliminating the use of toxic chemicals, and designing out waste through a superior design of systems, and within that, also new BMs (EMF, 2013).

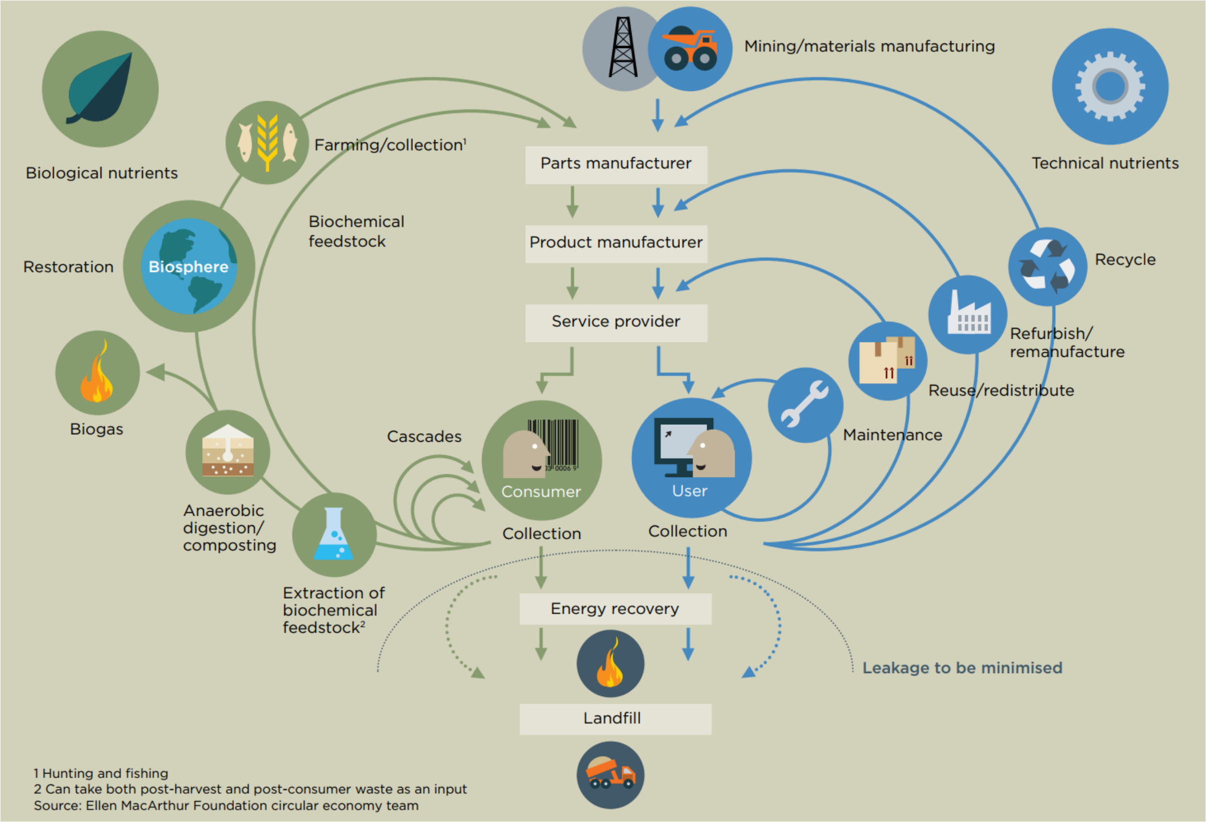
The concept of CE is relatively new, but CE-related practises have been in use for a very long time (SALVADOR *et al.*, 2020). Since the first mention of the core concept of CE (BOULDING, 1966) and when the term CE was coined (PEARCE; TURNER, 1990), the concept of CE has been shaped by many schools of thought. Those include the Laws of Ecology (COMMONER, 1971), Industrial Ecology (GRAEDEL; ALLENBY, 1995), Regenerative Design (LYLE, 1996), Biomimicry (BENYUS, 1997), Natural Capitalism (LOVINS *et al.*, 1999), Cradle to Cradle (MCDONOUGH; BRAUNGART, 2002), Performance Economy (STAHEL, 2010), and the Blue Economy (PAULI, 2010).

Key actors towards accelerating the transition to a CE include the Ellen MacArthur Foundation (EMF, 2013), the British Standards Institute (BSI) for elaborating the first standard on CE, the BS 8001 (BSI, 2017), and organisations such as the World Business Council for Sustainable Development (WBCSD) (WBCSD, 2017). Those have been providing guidance on how to implement and manage more circular businesses.

A CE is said to be based on four building blocks (EMF, 2013): (i) CE Design, which encompasses considering the concept and principles of CE from the very design of systems; (ii) New BMs, which comprise innovative actions towards cleaner value offer and capture; (iii) Reverse Cycles, enabling the return of resources along the supply chain for value (re)capture and re-cycling of materials, and; (iv) Enablers and Favourable System Conditions, embedding aspects that facilitate CE implementation and management, such as establishing partnerships, governmental support and incentive, development of technology, and scaling up systems.

The possibilities in a CE are easily described using the butterfly diagram, by the Ellen MacArthur Foundation, as depicted in Figure 2 (page 27).

Figure 2 - Butterfly diagram



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation circular economy team

Source: EMF (2013)

In a CE, there is the technical cycle (in blue in Figure 2) and the biological cycle (in green in Figure 2). The biological cycle describes the interactions with the natural environment, whereas the technical cycle describes the interactions within the Technosphere. In a CE, one should make use of opportunities in both cycles (but especially in the technical cycle) in order to find ways to use natural resources in a responsible way and re-use them for as long as possible.

Nonetheless, greater circularity *per se* might not result in greater sustainability of systems. Therefore, it has been observed that transitioning to an economy based on renewable resources can help alleviate the worrying conditions of Earth’s carrying capacity (STEFFEN *et al*., 2015), thus lowering environmental impacts, where a BE emerges.

2.2 BIOECONOMY (BE)

The term bioeconomy seems to have been coined in the 1990s, by Enriquez (1998), when highlighting the significance and potential applications of genomics. A BE encompasses both producing and converting renewable biological resources into bio-based products of high-value, including food, feed, biochemical products, and bioenergy (EUROPEAN COMMISSION, 2018). Concisely, in a BE, bio-based resources are used to make high-added-value products.

The use of biomass as a raw material is not new. However, a BE prompts the use of biomass resources for high ends (MODESTO *et al*., 2021) using environmentally preferable technology, often in biorefineries (IMBERT, 2017). A biorefinery is the processing of biomass feedstock into marketable products (including food, feed, materials and chemicals, fuels, power, and heat) using adequate conversion technologies (SONNENBERG *et al*., 2007; UBANDO *et al*., 2020). It is where different technologies are used to convert bio-resources into highly valued products (FERREIRA, 2017). Biorefineries are composed of 4 main conversion platforms, which include chemical, thermochemical, mechanical, and biological conversions (UBANDO *et al*., 2020).

A BE embeds the many sectors that produce, process, and use bio-based resources including, for instance, forestry (NÄYHÄ, 2019), agriculture (HAGMAN *et al*., 2019), and livestock (ROOS; STENDAHL, 2015), for a variety of ends such as food, feed, bio-based materials, and bioenergy (D'AMATO *et al*., 2017). In a BE, to some extent, resources already are circular by nature (VANHAMÄKI *et al*., 2019), providing greater environmental sustainability (PAREDES-SÁNCHEZ *et al*., 2019). However, BEs are very diverse, as they might vary significantly from place to place, depending on the characteristics of the region (regarding, e.g., potential and availability of bioresources, and logistic distances); therefore, a BE might not always be sustainable (VANHAMÄKI *et al*., 2019), and there can be no one single BE model (EGEA *et al*., 2018).

Rather than fossil resources, biological ones are to be explored in the transition to a BE, and wastes or by-products (i.e., side-streams) should be exploited for a more environmentally sustainable value creation (KLITKOU *et al*., 2019) in order to establish more circular systems.

Even though society produces large quantities of solid waste (MAINA *et al.*, 2017), and approximately 46% of municipal solid waste is organic (CAMPUZANO; GONZÁLEZ-MARTÍNEZ, 2016), bioresources come not only from waste. Potentially, biomass resources are some of the most sustainable and largely available sources of energy on the planet (PAREDES-SÁNCHEZ *et al.*, 2019) and might come from (e.g.) forests, agriculture, also forestry and agricultural industries (PAREDES-SÁNCHEZ *et al.*, 2019), as well as livestock farming and related activities.

BE has been greatly considered to power the substitution of fossil-based industrial inputs for bio-based ones, establishing a more environmentally sustainable use of renewable resources (WINKEL, 2017). Nonetheless, criticism has been launched over BE in case it is unable to bring environmental benefits from the substitution of fossil resources with bio-based ones if these are not managed properly (MUSTALAHTI, 2017). D'Amato *et al*. (2020) advocate that a circular BE must include sustainable sourcing/management of bio-sources, and aim at use rather than ownership, thus being more than just “more circular”.

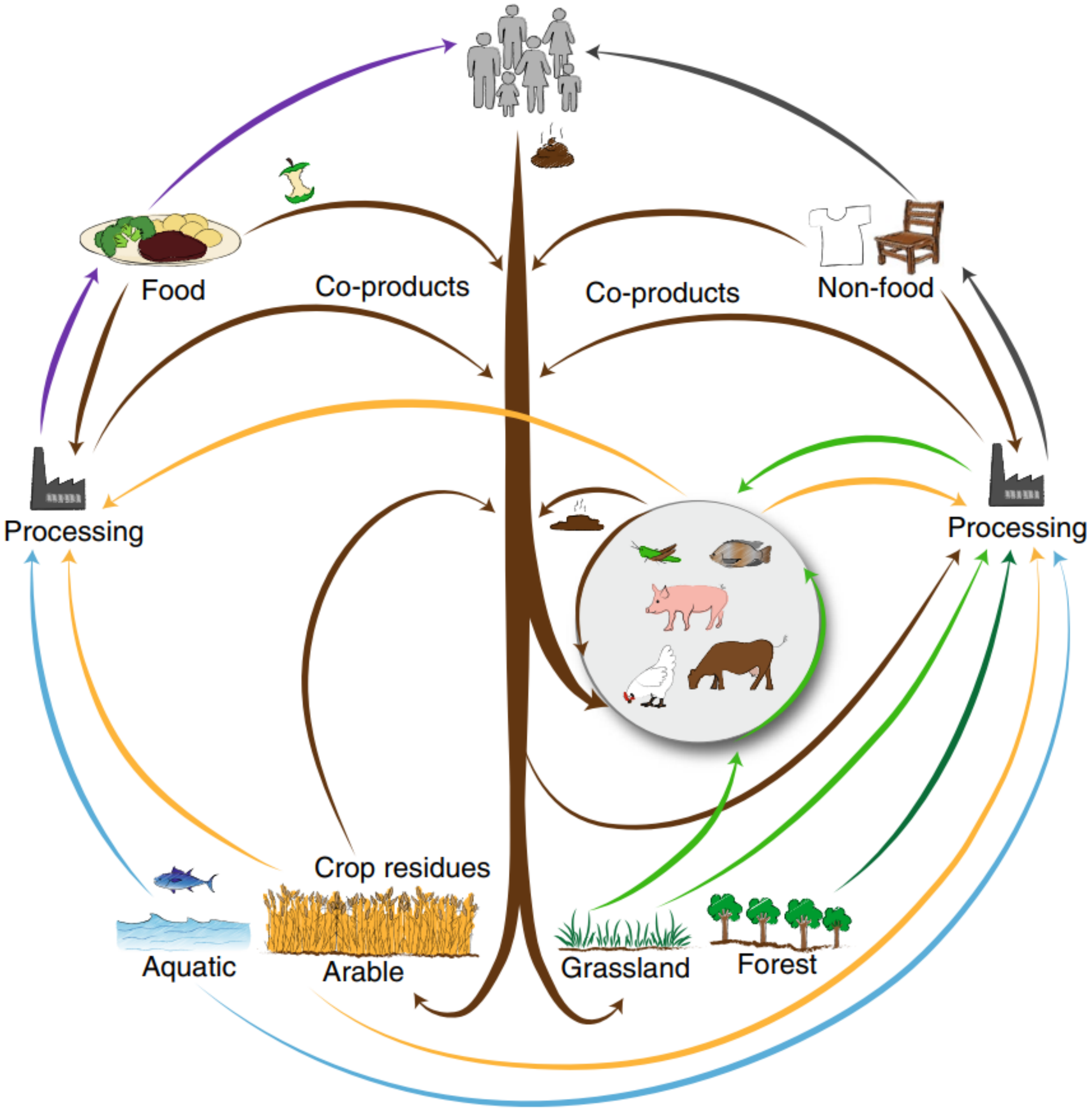
A resource-efficient use of biomass calls not only for the replacement of some inputs for biowaste, but mainly for the cascaded use of bioresources, increasing the added value and decreasing volumes of consumption of virgin resources (KLITKOU *et al.*, 2019), thus advocating for a CBE, as highlighted by the European Commission (EUROPEAN COMMISSION, 2018).

2.3 CIRCULAR BIOECONOMY (CBE)

Recently, the CBE has been gaining attention, especially due to the UN’s Sustainable Development Goals (SDG) (D'AMATO *et al.*, 2020), since it can contribute to the achievement of many of them, for instance by contributing to eradicate hunger (SDG 2), enabling a more sustainable conduct towards clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), decent work and economic growth (SDG 8), industry, innovation and infrastructure (SDG 9), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), climate action (SDG 13), life below water (SDG 14), and life on land (SDG 15).

BE and CE overlap (CARUS; DAMMER, 2018) in the concept of a CBE. A CBE uses bioresources to make high-value-added products in a more sustainable way, cascading the use of materials, and minimising the consumption and leakage of resources to the environment. It delivers both environmental and economic benefits (MOHAN *et al*., 2018), by preventing pollution (from the recovery of waste streams) and promoting potential valorisation (by making marketable products from waste) (PRASAD, 2015). A simplified scheme of the potential biomass flows in a CBE can be seen in Figure 3.

Figure 3 - Biomass flows in a circular bioeconomy



Source: Muscat *et al.* (2021)

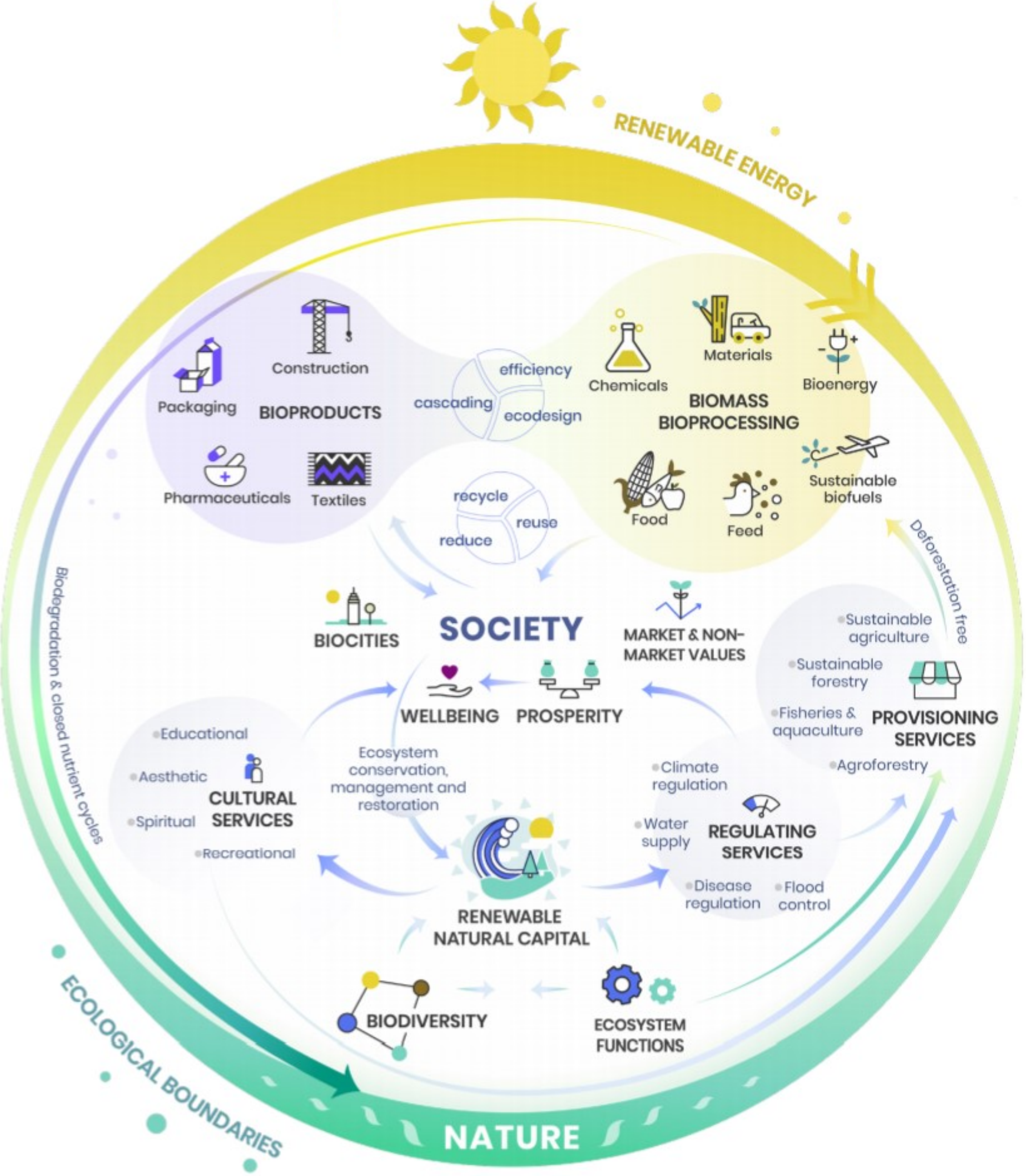
From Figure 3 one can observe that although the BE is the basis for the food system, biomass resources are used to produce both food and non-food products, and it is possible to establish a closed-loop system where both environmental and economic aspects are accounted for, where aquatic and land (arable, grassland and forest) biomass resources are used in processing and consumption, and both by-products and wastes go back into the system by the many potential strategies for re-cycling. Muscat *et al*. (2021, p. 1) yet outlines that a CBE can aid greater sustainability by:

> "safeguarding and regenerating the health of our (agro)ecosystems; avoiding non-essential products and the waste of essential ones; prioritizing biomass streams for basic human needs; utilizing and recycling by-products of (agro)ecosystems; and using renewable energy while minimizing overall energy use."

Furthermore, Palahí *et al*. (2020) present the concept of the CBE of wellbeing (see Figure 4, page 32), where it is centred on people and the natural environment and aims for a sustainable wellbeing.

The CBE of wellbeing still places society at the centre and is built around the sectors of the existing economy but seeking to switch societal activities (and products) to renewable sources, respecting ecological boundaries. On top of being a solution to urgent environmental priorities, such as biodiversity loss, climate change, food loss and waste, land use change, and resource scarcity, the CBE is said to carry a USD 7.7 trillion opportunity until 2030 (WBCSD, 2019). Exploring the possibilities within a CBE can unlock opportunities from a business perspective. It enables creating new markets and entering customer segments, by sourcing responsibly and enabling new value chains; it provides competitive advantage, by enabling businesses to lower the environmental impacts of their activities; it mitigates regulatory and societal risks, by reducing risks of potential (upcoming) regulations and being at the vanguard in societal shifts (WBCSD, 2019).

Figure 4 - The circular bioeconomy of wellbeing



Source: Palahí *et al.* (2020)

Therefore, Reim *et al*. (2019) stress that for our society to be able to rely on bio-based sources, their use needs to allow achieving economic growth. Hence, it is of undeniable importance for companies to get to know the concepts around BMs and CBMs, how they are structured and conceived, and use them to enable a CBE.

2.4 CIRCULAR BUSINESS MODELS (CBM)

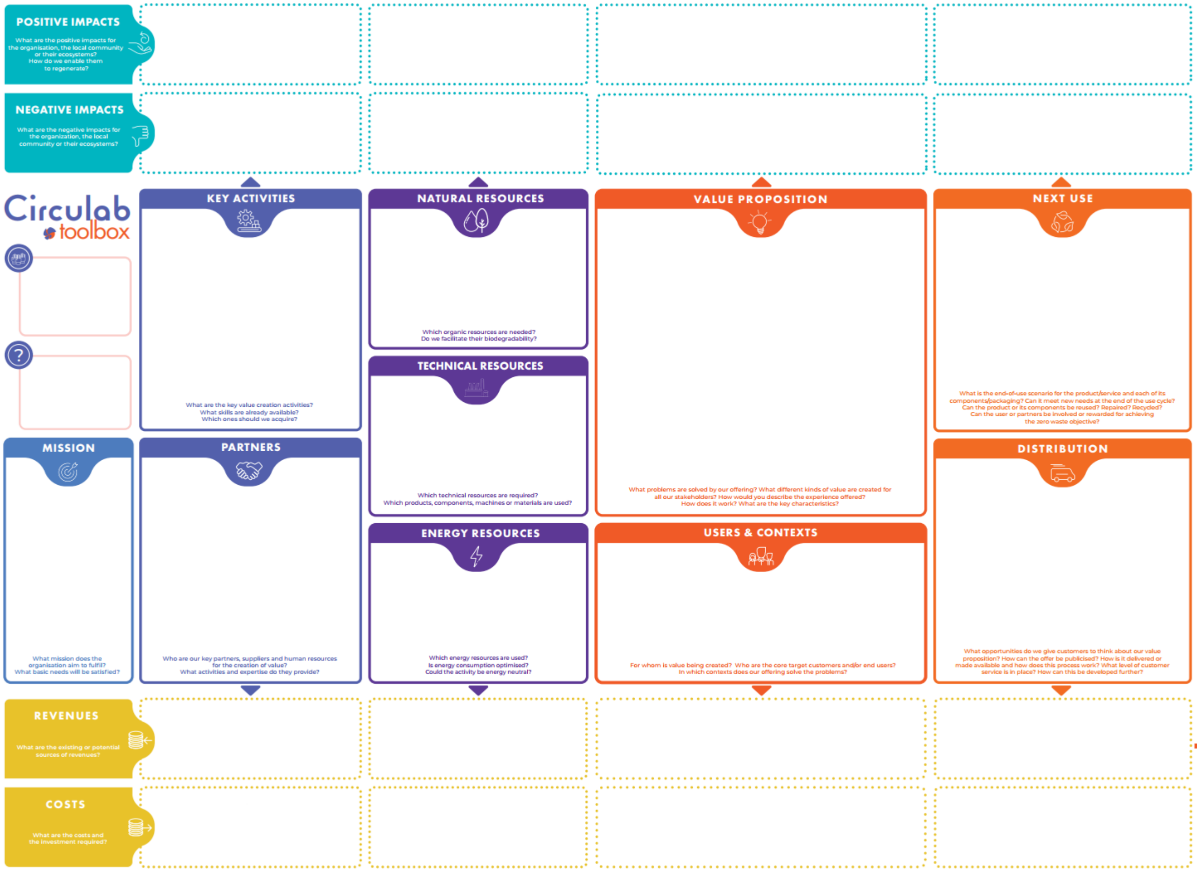
The BM of a company is the way it does business. It is a conceptual and simplified representation of what value will be offered to consumers (WIRTZ *et al*., 2016), its characteristics and relationships with all stakeholders, thus showing how it will be done, and the related financial consequences (OSTERWALDER *et al*., 2005). Every company runs a BM, either knowingly or unknowingly, using its strategic resources to create value via meeting customers' needs (TEECE, 2010). What is more, the operationalisation of a BM allows a company to create its business plan, thus setting their BM into practise. That can be done by breaking down business strategies into small tactical and operational activities which can be realised and monitored on a frequent basis. Overall, a BM comprises strategies for value proposition, creation and delivery, and capture (RICHARDSON, 2008).

Value proposition entails what value will be offered to customers. This is how a company differentiates from others (RASMUSSEN, 2007). Value creation and delivery depicts how value comes to be, thus created or co-created throughout the value chain and the means used for communicating and delivering that value to customers (PIERONI *et al*., 2018; TEECE, 2010). Value creation and delivery involves key activities, resources, and partners, as well as distribution channels (OSTERWALDER; PIGNEUR, 2010). Value capture, in turn, describes how value is captured, retained, and transformed into results, thus making the financial model of the company (TEECE, 2010; TUKKER, 2015). What is more, value capture (for actors other than the company, i.e., the environment and societal actors) also includes the creation of competitive advantage as well as additional income for key partners, embedding support to job creation, improved consumption choices and quality of life for consumers, and reduced environmental and societal impacts (D'AMATO *et al*. 2020).

The most widely used and accepted representation of BMs currently is the BM Canvas, proposed by Osterwalder and Pigneur (2010). However, the BM Canvas was not built for circularity and is best suited to depict linear BMs (KOZLOWSKI *et al*., 2018; SALVADOR *et al*., 2021c). Many attempts of further development of the BM Canvas to include circularity do exist, such as the triple layered Canvas (JOYCE; PAQUIN, 2016), the Backcasting and Eco-design for the Circular Economy (BECE) framework (HEYES *et al*., 2018), the reDesign Canvas (KOZLOWSKI *et al*., 2018), among others.

Nevertheless, one of the most comprehensive tools to depict CBMs is the Circular Canvas (CIRCULAB, 2021), as it accounts for the valorisation or next use of the product and/or the materials that make it, considers the positive and negative impacts of a product system, and specifies the types of resources (natural, technical, and energy) used within that system. The Circular Canvas (in Figure 5) is made of 14 building blocks, which include: users and contexts, value proposition, revenues, costs, mission, key activities, partner, natural resources, technical resources, energy resources, next use, distribution, positive impacts, and negative impacts.

Figure 5 - Circular Canvas



Source: CIRCULAB (2021)

(i) *Users and contexts* defines to whom the value being created and who are the core target customers and/or end users.

(ii) *Value proposition* defines what problems are solved by the company's offering, what different kinds of value are created for all the different stakeholders, what the experience offered is, how it takes place, and its key characteristics.

(iii) *Revenues* defines what the existing or potential sources of revenues are.
(iv) *Costs* defines what the costs are and what investments are required.
(v) *Mission* defines what mission the organisation aims to fulfil and what basic needs will be satisfied.
(vi) *Key activities* defines what the key value creation activities are, what skills are already available, and which ones should be acquired.
(vii) *Partners* defines who the organisation's key partners, suppliers, and human resources for the creation of value are, and what activities and expertise they provide.
(viii) *Natural resources* define what organic resources are needed and whether/how biodegradability is facilitated.
(ix) *Technical resources* defines what technical resources are required, and what products, components, machines and/or materials are used.
(x) *Energy resources* defines what energy resources are used, whether energy consumption is optimised, and whether the activity could be energy neutral.
(xi) *Next use* defines what the end-of-use scenario is for the product/service and each of its components/packaging, whether it can meet new needs at the end of the use cycle, whether the product or its components can be reused, repaired, or recycled, and whether the user or partners can be involved or rewarded for achieving the zero-waste objective.
(xii) *Distribution* defines what opportunities the company gives customers to think about their value proposition, how the offer can be publicised, how it is delivered or made available and how this process works, what level of customer service is in place and how this can be developed further.
(xiii) *Positive impacts* defines what the positive impacts are for the organisation, the local community, or their ecosystems, as well as how the company enables them to regenerate.
(xiv) *Negative impacts* defines what the negative impacts are for the organisation, the local community, or their ecosystems.

Being one of the pillars of CE (EMF 2013), BMs need to enable greater circularity (BOCKEN *et al*., 2017). A CBM is a BM that enables regenerative systems, seeking to maintain the value of resources at their maximum (for as long as possible), and to eliminate or reduce resource leakage, using strategies for slowing, narrowing, or closing resource flows (BOCKEN *et al*., 2016; SALVADOR *et al*., 2020).

It is defended by Lewandowski (2016) that CBMs should feature at the core of a CE, since they assist promoting longer lifetimes of products, parts of products, or resources/materials, by means of strategies for closing loops via successive cycles (NUSSHOLZ, 2018). Nonetheless, although conceiving new BMs might make the implementation of CE aspects easier, it is not the only alternative. Existing BMs can also adapt/rethink their strategies for value offer and capture. A well-designed BM can become a source of competitive advantage, rather than only a way of externalising a company's business strategy. Furthermore, greater circularity is often tied to reduced consumption of resources, which is an environmental issue of critical importance.

As new or adaptive BMs call for innovation, companies need to embed characteristics such as the ability to learn from mistakes, and to regenerate, as well as agility, and flexibility, to their culture (NÄYHÄ, 2020); hence the need for a change from the inside out. Robust CBMs would be resilient, and CE (BENYUS, 1997; PAULI, 2010) suggests building resilience through diversity. Nonetheless, having a business with diverse offers allows for a great variety of stakeholders' views (NÄYHÄ, 2020), which requires good and comprehensive stakeholder relationship skills.

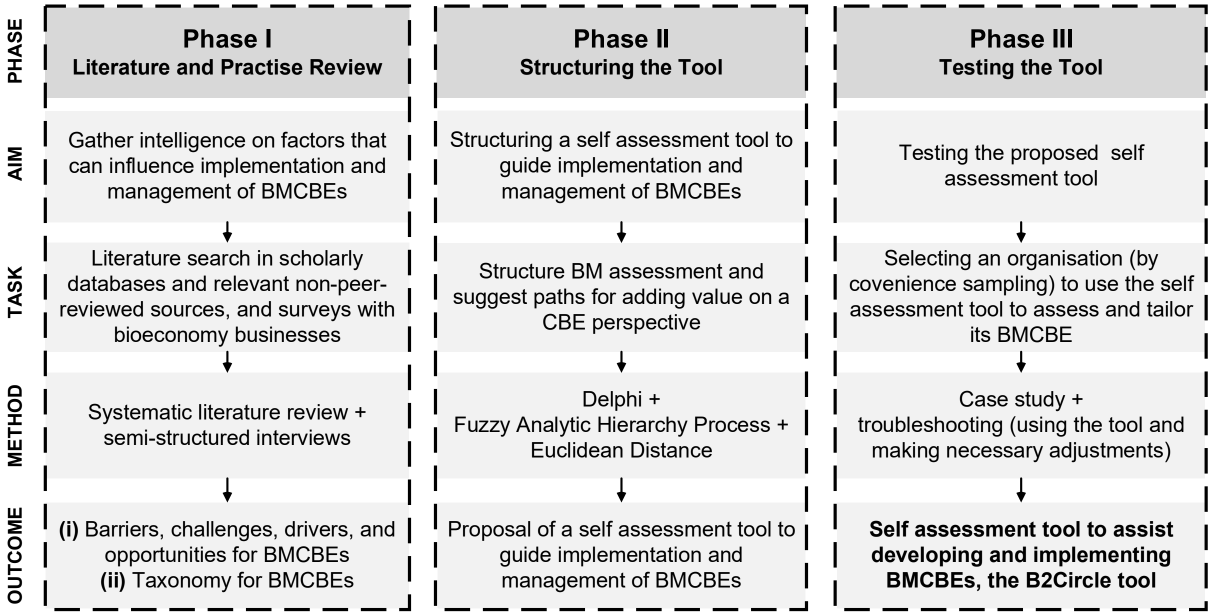
In CBMs, just as in a CE, either with a diverse or a limited portfolio, a company needs to adapt, taking advantage of local resources towards approaches tailored to the sector it belongs to, the customer segments it directs actions to, and with the resources it has available. What is more, Mohan *et al*. (2018) state that more sustainable BMs need to be developed if a BE is to succeed. Hence, the need of BMs for a CBE.

Having laid the theoretical background necessary to support the development of this dissertation, the next chapter begins addressing the methods used in this research.

3 METHODS

The methods to conduct this dissertation were divided into three Phases, which are (I) Literature and Practise Review, (II) Structuring the Tool, and (III) Testing the Tool, as illustrated in Figure 6.

Figure 6 - Overview of research methods



PHASE	**Phase I** **Literature and Practise Review**	**Phase II** **Structuring the Tool**	**Phase III** **Testing the Tool**
AIM	Gather intelligence on factors that can influence implementation and management of BMCBEs	Structuring a self assessment tool to guide implementation and management of BMCBEs	Testing the proposed self assessment tool
TASK	Literature search in scholarly databases and relevant non-peer-reviewed sources, and surveys with bioeconomy businesses	Structure BM assessment and suggest paths for adding value on a CBE perspective	Selecting an organisation (by covenience sampling) to use the self assessment tool to assess and tailor its BMCBE
METHOD	Systematic literature review + semi-structured interviews	Delphi + Fuzzy Analytic Hierarchy Process + Euclidean Distance	Case study + troubleshooting (using the tool and making necessary adjustments)
OUTCOME	**(i)** Barriers, challenges, drivers, and opportunities for BMCBEs **(ii)** Taxonomy for BMCBEs	Proposal of a self assessment tool to guide implementation and management of BMCBEs	**Self assessment tool to assist developing and implementing BMCBEs, the B2Circle tool**

BMCBE – business model for a circular bioeconomy

Source: Author (2021)

Each Phase had an intent. Phase I intended to provide the necessary theoretical background on BMCBEs by investigating the existing literature and business practises. Phase II intended to aid building the tool by structuring how a business will assess its existing or desired BM and then bridge the gap between the current state (no existing business or existing BM) and the desired state (new or adapted BM) by analysing the company's desired approach and matching it to the most suitable of the BMCBEs defined in Phase I. In Phase III the proposed tool was tested, and any adjustments deemed necessary were made. It also enabled to provide guidance to the organisation where the tool who used the tool for the first time. Moreover, each phase had different contributions to fulfilling each of the specific objectives of this dissertation, as outlined in Table 2 (page 38).

Table 2 - Contribution of research phases to specific objectives

Research Phase	Specific Objective
Phase I - Literature and Practise Review	i. Identify the barriers, challenges, drivers, and opportunities for businesses in a circular bioeconomy
	ii. Identify overarching business models for a circular bioeconomy
	iii. Define criteria to profile and to set apart the overarching business models for a circular bioeconomy identified in ii
Phase II - Structuring the Tool	iii. Define criteria to profile and to set apart the overarching business models for a circular bioeconomy identified in ii
	iv. Propose a method to assess the overarching business models for a circular bioeconomy identified in ii and the (existing or desired) business model of an organisation using the tool
	v. Propose a method to recommend which overarching business model for a circular bioeconomy best fits an organisation using the tool
Phase III - Testing the Tool	vi. Select an organisation to test the tool vii. Use the tool to recommend a business model to the selected organisation viii. Conduct an analysis of the selected organisation (and its product system) to make specific recommendations for improved circularity based on the recommended business model

Source: Author (2021)

The methods used in each Phase are presented in the following sections.

3.1 METHODS FOR THE LITERATURE AND PRACTISE REVIEW - PHASE I

This research adopts a mixed-method approach comprising a systematic literature review (SLR) (see section 3.1.1 - Stage I), and a set of semi-structured interviews (see section 3.1.2 - Stage II). Stage I comprised an SLR, and Stage II comprised semi-structured interviews with BE businesses. Both Stages had the intent of identifying drivers, opportunities, barriers, and challenges for businesses in a CBE as well as gather intelligence to propose a taxonomy for BMCBEs.

3.1.1 Systematic Literature Review (SLR) - Stage I

A series of Steps, presented in Figure 7 and described thereafter, were followed to conduct the review.

Figure 7 - Steps for systematic literature review

			ST1	**ST2**
Searches in databases	**1**	Searches in databases	ScienceDirect: **396** Scopus: **748** Web of Science: **491**	ScienceDirect: **15** Scopus: **21** Web of Science: **25**
		Filter	**Documents Remaining**	**Documents Remaining**
Filters	**2**	Deleting duplicates and documents written in a language other than English	918	31
	3	Reading titles & keywords	246	30
	4	Reading abstracts	144	29
	5	Reading full-texts	113	19
Complement	**6**	Complementing the portfolio	-	10
		Final Portfolio	**113**	**29**
Content analysis	**7**	Content used from the documents	Identifying: - *Barriers* - *Challenges* - *Drivers* - *Opportunities* **Section 4.1**	Background for: *Taxonomy for Business Models for a Circular Bioeconomy* **Section 4.4**

Source: Author (2021)

Step 1: Searches in databases. The searches were conducted on September 6, 2021, on the ScienceDirect, Scopus, and Web of Science databases. The searches sought to cover all available literature up to that date, with no restrictions on type of document (thus including journal articles – both research and review, and published and in press –, conference articles, books, and book chapters). Two searches were conducted, using different strings, for different purposes.

Search string 1 (ST1): *(("circular* econom*" OR "CE") AND ("bioeconom*" OR "bio econom*" OR "bio-based econom*")) OR ("circular*" AND ("bioeconom*" OR "bio econom*" OR "bio based-econom*")),* returned 1,635 documents and was aimed at identifying barriers, challenges, drivers, and opportunities for BMCBEs (see section 4.1). Search string 2 (ST2): *(("circular econom*" AND ("bioeconom*" OR "bio econom*" OR "bio-based econom*")) OR ("circular bioeconom*")) AND ("business model*"),* returned 61 documents and was aimed at providing the background to propose a taxonomy for BMCBEs (see section 4.4).

Step 2: Deleting duplicates and documents written in a language other than English. All duplicate documents were deleted, as well as the ones not written in English. Thus, only unique documents in English remained after Step 2. 919 documents remained for ST1 and 31 for ST2 after this Step.

Step 3: Reading title & keywords. All titles and keywords were read and the question that guided either keeping or excluding the documents from ST1 was “does this research contribute to identifying drivers, opportunities, challenges and/or barriers for businesses in a CBE?”, and for ST2 was “does this research contribute to identifying and structuring BMCBE?”. These same questions (for the respective ST) guided the researcher when going through Steps 4 and 5. 246 documents remained for ST1 and 30 for ST2 after this Step.

Step 4: Reading abstracts. All abstracts were read and analysed according to the same questions as in Step 3. 144 documents remained for ST1 and 29 for ST2 after this Step.

Step 5: Reading full texts. The full texts of the remaining documents were retrieved and read in full. When reading the full texts, the studies were analysed according to the same questions as in Step 3. 114 documents remained for ST1 (see Table A. 1) and 19 for ST2 (see Table A. 2) after this Step.

Step 6: Complementing the portfolio. To complement the portfolio, further searches were conducted to retrieve other documents published by well-known and worldwide recognised organisations known to help accelerate the transition to a CE, such as the EMF and the WBCSD. To that end, non-systematic searches were conducted on the websites of those organisations, seeking to identify documents that provided relevant content for a better understanding of a CBE and BMCBEs. The 10 documents used from those sources can be seen in Table A. 2 under “Report” as the Type of Publication.

Step 7: Content Analysis. This Step comprised the content analysis and was conducted during the reading of the full texts of the documents in the final portfolio. During the reading of full texts, the author used reading forms for registering the barriers, challenges, drivers, and opportunities for businesses in a CBE, and the respective literature supporting each of them (from ST1), as well as the BMCBEs (from ST2), and their supporting literature. The results of these analyses can be seen in Chapter 4.

3.1.2 Practise Review (PR) - Stage II

To gather information on the barriers, challenges, drivers, and opportunities towards greater circularity in BE businesses from a practical perspective, and to spot strategies related to different BMs in a CBE, a set of companies were contacted. Invitations were sent to individual companies, research institutes, and collective organisations (i.e., clusters or company associations) in the continents of Africa, America (including North, Central, and South America), Asia, Europe, and Australia. From those contacted, representatives from 32 individual organisations, research institutes, and collective organisations agreed to be interviewed. The contacts were made using a range of strategies: (i) convenience sampling (contact details provided specialists in BE businesses, colleagues of the author of this research), (ii) looking up BE-organisations in reports (such as from the EMF, Economic Commission for Latin America and the Caribbean (ECLAC)), (iii) accessing websites of collective organisations and groups of companies such as BioEconomy Alberta and the Bio-based Industries Joint Undertaking (BBIJU), and (iv) searching for BE-based businesses on common search engines. One representative from each of the 32 organisations were contacted and interviewed remotely from February to July 2021. The questions used in the semi-structured interviews are shown in Table 3 (page 42).

Table 3 - Content of semi-structured interviews

Identification	- Name of organisation - Type of organisation (Cluster, Individual Company, Research Institute) - Country - Main sector/activity (Biochemical, Bioeconomy, Bioenergy, Chemical Products, Consulting, Digitisation, Engineering, Food and Feed, Forestry, Livestock, Pharmaceutical, Recycling, Textile) - Size of organisation (micro, small, medium, large) - Interviewee's name and email address - Position in the organisation (Business Owner, Engineer, Manager, President/Director, Researcher/Analyst, Specialist/Consultant, Team Leader) - How long in the position (years)
Topic-specific questions	- What is your view of a Circular Economy (CE) / Circular Bioeconomy (CBE)? - Does your organisation use or enable any CE/CBE concepts? Why (main motivation for the practise(s) to be undertaken)? - If Yes. How does CBE take place in your organisation? - What are/have been (in case there are circular practises in place) barriers, challenges, drivers, and opportunities for your organisation to engage in more circular practises? - If No. If you were to implement CBE practises, how do you think CBE would take place in your organisation? - What would be (in case there are not circular practises in place) barriers, challenges, drivers, and opportunities for your organisation to engage in more circular practises?

Source: Author (2021)

The demographics of the interviewees can be seen in section 4.2.1 and in Table 4 (page 43).

For Country, the country considered for demographic purposes was the one where the CBE practises took place. A company’s office might be based in one country but its operations (manufacturing, or project implementation) in another.

For Type of organisation, “Cluster” comprised groups of organisations, collective initiatives/projects, and community organisations.

For Main sector/activity, “Bioeconomy” was used for all companies under Cluster as type of organisation, since organisations of different sorts were part of those groups.

For Company size, the following categories were considered (according to the number of employees): micro (up to 9 employees), small (10-49), medium (50-249), large (250+). Moreover, all organisations whose type of organisation was Cluster were labelled as large.

The topic-specific questions “What is your view of a Circular Economy (CE)/ Circular Bioeconomy (CBE)?”, and “Does your organisation use or enable any CE/CBE concepts? Why (main motivation for the practise(s) to be undertaken)?” were asked as starting points to capture interviewees’ knowledge and perception about CE and CBE.

Table 4 - Profiles of organisations that participated in the practise review

Organisation ID	Type of organisation	Country (based in)	Position of interviewee	How long in the position (years)	Main sector/activity	Size of organisation	Duration of interview (min)
1	Cluster	Denmark	Team Leader	1	Bioeconomy	Large	28
2	Individual Company	Netherlands	Specialist/Consultant	1	Recycling	Small	22
3	Cluster	Greece	President/Director	5	Bioeconomy	Large	21
4	Individual Company	Portugal	Engineer	13	Bioenergy	Large	15
5	Individual Company	Portugal	Manager	7	Engineering	Large	16
6	Individual Company	Portugal	President/Director	1	Food and Feed	Medium	17
7	Individual Company	Mexico	Business Owner	3	Bioenergy	Micro	25
8	Individual Company	Portugal	Manager	3	Consulting	Medium	35
9	Individual Company	Finland	Manager	2	Forestry	Large	32
10	Cluster	Spain	Researcher/Analyst	1	Bioeconomy	Large	35
11	Individual Company	Netherlands	President/Director	3	Engineering	Large	18
12	Individual Company	Norway	Manager	3	Engineering	Small	29
13	Individual Company	Germany	Engineer	10	Bioenergy	Small	26
14	Individual Company	France	Business Owner	2	Engineering	Small	20
15	Individual Company	Spain	President/Director	15	Chemical Products	Large	23
16	Individual Company	Rwanda	Business Owner	3	Food and Feed	Small	21
17	Research Institute	Spain	Manager	7	Textile	Large	15
18	Individual Company	Rwanda	Business Owner	5	Food and Feed	Medium	25
19	Individual Company	Kenya	Business Owner	6	Biochemical	Small	14
20	Cluster	Kenya	Team Leader	12	Biochemical	Large	24
21	Individual Company	Burundi	Business Owner	9	Biochemical	Medium	27
22	Cluster	Burundi	Business Owner	13	Food and Feed	Large	16
23	Individual Company	Australia	Business Owner	2	Bioenergy	Small	11
24	Research Institute	Brazil	Researcher/Analyst	6	Livestock	Large	22
25	Cluster	Brazil	President/Director	10	Pharmaceutical	Large	22
26	Individual Company	Argentina	Manager	3	Bioenergy	Large	19
27	Individual Company	South Africa	Specialist/Consultant	1	Bioeconomy	Small	23
28	Individual Company	Netherlands	President/Director	0.33	Digitization	Small	20
29	Individual Company	Australia	Manager	1	Bioenergy	Large	20
30	Individual Company	Brazil	Researcher/Analyst	0.25	Bioenergy	Medium	20
31	Individual Company	United States of America	Business Owner	4	Food and Feed	Small	25
32	Individual Company	Brazil	Manager	12	Biochemical	Large	25

Source: Author (2021)

The question “How does CBE take place in your organisation?” or “How do you think CBE would take place in your organisation?” served the purpose of helping the researcher draw a picture of the activities at the organisation and identify possible CE strategies in place and BMs running in the organisation, which helped build the overarching BMCBEs (presented later in section 4.4).

The question “What are/have been/would be barriers, challenges, drivers, and opportunities for your organisation to engage in more circular practises?” was aimed at identifying potential barriers, challenges, drivers, and opportunities that would affect CE practises (presented later in sections 4.1 and 4.2).

3.1.3 Proposing a Taxonomy for Business Models for a Circular Bioeconomy - Stage III

Both Stages I and II (the literature and the practise reviews) provided the background to propose a taxonomy for BMCBEs. The following methodological procedures were adopted to synthesise the list of overarching BMCBEs.

3.1.3.1 Listing existing and potential CBE strategies

From the systematic literature review (ST2), the full text of each document in the final portfolio was analysed. In those pieces of research, the authors listed CE strategies used in BE-based businesses. Besides that, the researcher analysed the recorded interviews from the practise review and added the relevant material to the list. That list contained strategies, practises, actions, activities, and/or concepts pointed out as being present in BE businesses. This initial list included similar, overlapping, and double-counted strategies.

3.1.3.2 Debugging the initial list of CBE strategies

The elements in the list of strategies went through pair comparisons to eliminate identical strategies and merge similar ones. Several rounds of excluding and merging were conducted until there was no overlap between any two strategies and it was no longer possible to merge (any two) or exclude them.

3.1.3.3Identifying overarching business models for a circular bioeconomy

In this step, the researcher organised related strategies in groups in order to identify dominant overarching BMCBEs. Several rounds of organising these groupings were necessary to achieve an initial list of BMCBEs.

3.1.3.4Checking for overlaps

After an initial list of overarching BMCBEs was defined, the researcher defined the aspects of value proposition, value creation and delivery, and value capture of those BMs to analyse them in greater detail. The BMs then went through pair comparisons to verify overlapping and ambiguous aspects of the initially defined overarching BMCBEs, and the need to merge or exclude any of them. More than one BM can be identified at the same time in the same organisation or product system. However, in order to be part of the list, the BMs needed to be mutually exclusive.

The BMs in the list were compared in pairs to one another, and no need to merge or exclude them was identified. Therefore, the seven BMs made the final list of overarching BMCBEs. The list of seven BMs, along with their description, can be seen in the results of Phase I, in section 4.4.

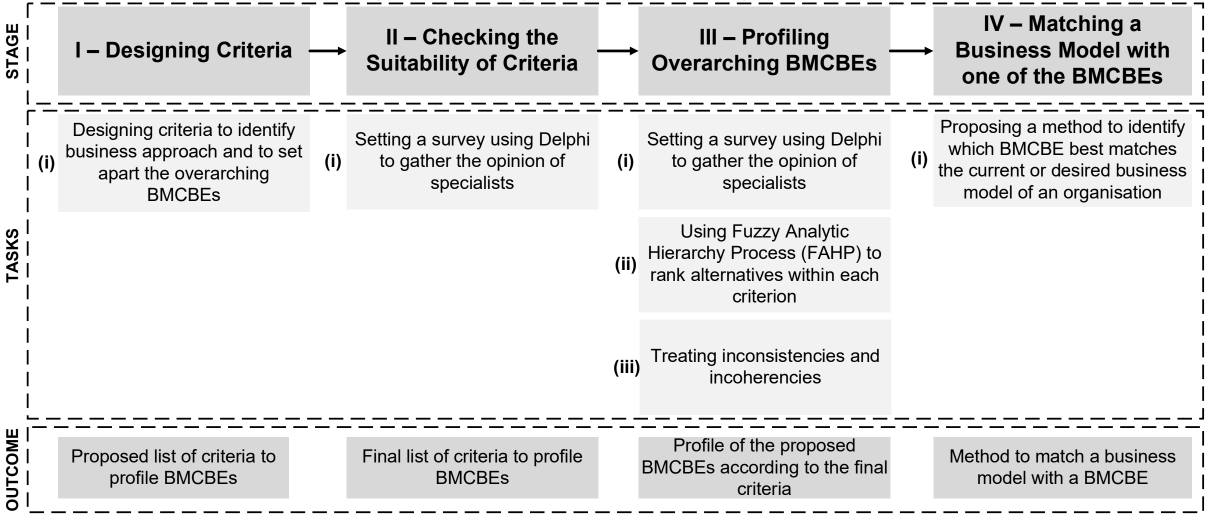
3.2 METHODS FOR STRUCTURING THE TOOL - PHASE II

To structure the tool, several stages were necessary, as illustrated in Figure 8 (page 58) and described hereafter.

3.2.1 Designing Criteria to Profile Business Approach and to Set Apart the Overarching Business Models for a Circular Bioeconomy - Stage I

It was necessary to define a set of criteria that could be used to both characterise the different overarching BMCBEs in the list and profile the business approach of an organisation. Therefore, during the systematic literature review the researcher sought to identify aspects within the 14 building blocks of the Circular Canvas (CIRCULAB, 2021) that could be used to profile BMCBEs.

Figure 8 - Stages for structuring the tool



BMCBE – business model for a circular bioeconomy

Source: Author (2021)

That was done aiming to both set apart the overarching BMs identified in Stage III of Phase I, and profile the business approach of an organisation using the same criteria. The criteria defined for each building block and the alternatives within each criterion are shown later in Chapter 5.

To define the criteria, and the alternatives within each criterion, an initial investigation was conducted looking up the keywords of each building block (retrieved from the questions/definitions presented in the Circular Canvas (CIRCULAB, 2021)) in the articles in the Final Portfolio (ST2), analysing the context in which those terms were involved. During this initial investigation the researcher collected other keywords that could help define aspects that would characterise that building block within BMCBEs. At the end of this initial investigation, the researcher had collected the set of keywords shown in Table 5 (page 47).

Thereafter, another round of investigation was conducted by looking up each of those keywords in each of the articles in the Final Portfolio (ST2). In this second round, the researcher sough to identify possible criteria and the alternatives within them, according to the existing literature, that would allow building a profile of a BMCBE. The list of criteria and alternatives is shown later in section 5.1.

Table 5 - Keywords used to search the articles in ST2 for aspects that could set apart business models according to the building blocks in the Circular Canvas

Building Block (BB)	**Keywords searched in the articles (what would set Business Models apart regarding each BB?)**
Users and Contexts	user; consumer; customer; stakeholder
Value proposition	value proposition; experience; cost; differentiation; focus; market segment; customer segment; consumer segment
Revenues	revenue; profit; value capture
Costs	cost; value capture; investment
Mission	mission; need; fulfil; purpose
Key activities	activity; activities; skill
Partners	partner; expertise; competency; competencies; collaboration; collaborator
Natural resources	natural resource; organic resource; end-of-life
Technical resources	technical resource; infrastructure; machine
Energy resources	energy; energy resource
Next use	end-of-life; end of life; EOL; life cycle; design out waste; upcycle; upcycling; downcycle; downcycling
Distribution	distribution; deliver; customer service
Positive Impacts	positive impact; impact
Negative Impacts	negative impact; impact

Source: Author (2021)

3.2.2 Checking the Suitability of Criteria - Stage II

Having defined the overarching BMCBEs (see section 4.4) and the criteria to profile those BMCBEs (see section 5.1), a survey (serving both Stages II and III of Phase II) was built to assess the suitability of the criteria to be used in the profiling of BMCBEs and to assess the seven BMCBEs according to the proposed set of criteria and alternatives. To that end, a survey was built on the platform Survey Monkey® and sent to specialists. The survey had two intents: (i) decide for each criterion whether it should be kept or excluded from the assessment, and whether new criteria should be used (if so, what they should be) (detailed in section 3.2.2), and (ii) profile each of the seven BMCBEs according to the final list of criteria (detailed in section 3.2.3). The survey was structured in 3 parts as follows:

a) Part 1: *Identification*. Respondents were asked to inform their name, institution, country, and email address. Expected completion time: *2min*. Part 1 was compulsory.

b) Part 2: *Reviewing and Assessing the Criteria*. The 19 criteria were displayed, and respondents were asked to assess the suitability of the criteria and their alternatives, whether any of the existing criteria should be excluded, and/or new criteria should be added to the assessment. Expected completion time: *4min*. Part 2 was compulsory.

c) Part 3: *Assessing the Business Models*. Each of the seven BMCBEs was shown on a separate page and respondents were asked to tell how representative of the strategies for a specific BM one alternative was in comparison to each one of the others. Part 3 was not compulsory, and respondents could choose to contribute by assessing any and as many BMs as they felt they could. Expected completion time: *5-7min* per BM.

In Part 3, respondents were asked to tell on a 9-point scale from “Extremely less important” to “Extremely more important”, how representative the alternatives in the 19 criteria were for implementing/managing a specific BM within a CBE context.

The structure of Parts 2 and 3 of que questionnaire is presented in Table B. 1 (page 190) and Table B. 2 (page 192), in Appendix B. The survey was part of a Delphi approach (details on the Delphi study are in section 3.2.4). In Part 2, respondents should indicate for each criterion whether it should be kept or excluded, and for each building block whether new criteria should be proposed to help set apart the seven BMCBEs. The final data were treated in the following way: if the majority (>50%) of respondents (by arithmetic average of responses) voted for the criterion to be kept, it was kept, otherwise, it was excluded. When new criteria were suggested, they went through three analyses: a) they were analysed to identify whether they could be used to characterise a BM rather than the activities in an organisation. For instance, if a participant suggested including the reach of the business (e.g., local, regional, global) as a criterion, it would be characterising the reach of the organisation, not the BM, as different organisations under the same BM might have different outreaches. Having passed that assessment, then b) the suggestion was analysed to investigate whether it was not already captured by one of the existing criteria and, in that case, if the description of the matching criterion needed adjusting or clarifying. Having passed that assessment, then c) new criteria were added to subsequent rounds of the Delphi method only if two or more respondents proposed the same or similar criteria. There were a few suggestions (Table 24, page 114), but none of them made it through b).

3.2.3 Profiling Overarching BMCBEs - Stage III

For profiling the overarching BMCBEs (Part 3 of the survey), the Fuzzy Analytical Hierarchy Process (FAHP) method was used. Analytical Hierarchy Process (AHP) was chosen for two main reasons. Firstly, because it is a compensatory method, and it allows ranking alternatives according to the judgement of experts. Secondly, because of its nature of pair comparison, relative to other ranking methods, it allowed for a smaller number of interactions, due to having many criteria with only two alternatives. There were other ranking methods, which are not necessarily for multi-criteria decision analysis (MCDA), such as the BORDA method, which lists the criteria and elects a representative aggregating the sum of the weighted preference ranking for each criterion (see BARAK; MOKFI, 2019). However, the number of interactions would be larger in case other methods were used.

Moreover, the Fuzzy AHP was chosen because it makes it easier for respondents to register their expert opinion (KIEU *et al*., 2021), rather than rate criteria and alternatives based on a numeric scale (CHANG *et al*., 2015), and it accounts for the uncertainty and vagueness of human judgment (KAYA; AYCIN, 2021), which is at the core of the fuzzy theory.

3.2.3.1 Fuzzy analytic hierarchy process

AHP, proposed by Saaty (1980), is one of the most well-known MCDA methods, and it has been one of the most widely used methods for MCDA (LEE *et al*., 2010). Nevertheless, even though classical AHP incorporates the opinions of specialists/experts, by itself it is unable to account for the vagueness (CHANG *et al*., 2015) and uncertainty (LEE *et al*., 2010) in human thoughts. When making a decision, decision-makers deal with a number of variables and weigh the trade-offs among those. On top of that, the nature of human thinking is not discrete. In that sense, Govindan and Murugesan (2011) claim that exact numerical values are not adequate for modelling human judgement, where the Fuzzy Logic, early addressed by Zadeh (1965), emerges.

Fuzzy Logic offers a solution to deal with “problems in which the source of imprecision is the absence of sharply defined criteria of class membership rather than the presence of random variables” (ZADEH, 1965, p. 339). Therefore, it can be used to model logical reasoning that contains imprecise and potentially vague statements. Fuzzy set theory is a method that allows measuring the ambiguity of concepts associated with human judgments, which is subjective. This includes linguistic terms, degree of satisfaction, and degree of importance, which are many times vague (SECME *et al*., 2009). For that reason, FAHP (GUMUS, 2009) and the use of triangular fuzzy numbers (TFN) is considered more effective and appropriate (compared to classical AHP) to overcome these limitations in systems where uncertain pairwise comparison takes place (CHAN *et al*., 2008).

Fuzzy set theory was introduced by Zadeh (1976), and it deals with approximate rather than exact reasoning. When using fuzzy theory, it is possible to quantify uncertain objects and events, and deal with the ambiguities surrounding the linguistic assessment (IM; CHO, 2013).

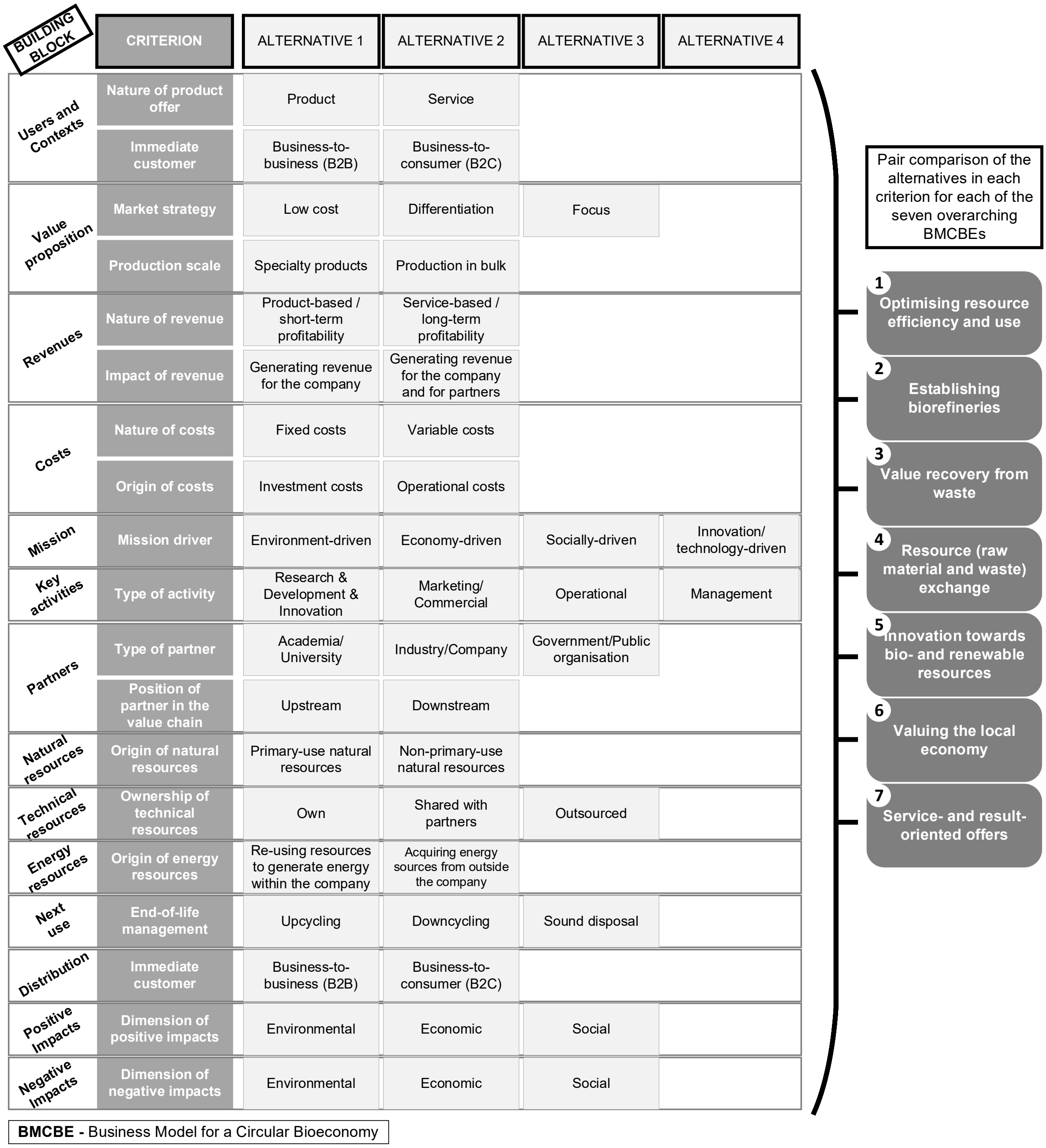
In this research, the FAHP was applied to each criterion in each building block as a separate assessment. Therefore, the process of applying FAHP, as illustrated in Figure 9 (page 51), took place 19 times for each of the seven overarching BMCBEs in the first round of the Delphi approach.

By conducting the assessment (pairwise comparison of the alternatives within each criterion) for each of the seven overarching BMCBEs, a profile of each of them was built.

Nonetheless, to provide a clearer picture of how the data in this research was treated using FAHP, one must be made aware of a few definitions, as defined by Zadeh (1965), and presented hereafter.

Definition 1: *Fuzzy set*. Fuzzy sets are defined by membership functions (MF). A fuzzy set (class) A in X is characterized by an MF $f_A(x)$ that associates a real number in the interval [0, 1] with each point in X, where the value of $f_A(x)$ at x represents the "grade of membership" of x in A, that is, the extent or degree to which x belongs to A.

Figure 9 - Overview of the assessment of business models for a circular bioeconomy according to 19 criteria



BUILDING BLOCK	CRITERION	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4
Users and Contexts	Nature of product offer	Product	Service		
	Immediate customer	Business-to-business (B2B)	Business-to-consumer (B2C)		
Value proposition	Market strategy	Low cost	Differentiation	Focus	
	Production scale	Specialty products	Production in bulk		
Revenues	Nature of revenue	Product-based / short-term profitability	Service-based / long-term profitability		
	Impact of revenue	Generating revenue for the company	Generating revenue for the company and for partners		
Costs	Nature of costs	Fixed costs	Variable costs		
	Origin of costs	Investment costs	Operational costs		
Mission	Mission driver	Environment-driven	Economy-driven	Socially-driven	Innovation/ technology-driven
Key activities	Type of activity	Research & Development & Innovation	Marketing/ Commercial	Operational	Management
Partners	Type of partner	Academia/ University	Industry/Company	Government/Public organisation	
	Position of partner in the value chain	Upstream	Downstream		
Natural resources	Origin of natural resources	Primary-use natural resources	Non-primary-use natural resources		
Technical resources	Ownership of technical resources	Own	Shared with partners	Outsourced	
Energy resources	Origin of energy resources	Re-using resources to generate energy within the company	Acquiring energy sources from outside the company		
Next use	End-of-life management	Upcycling	Downcycling	Sound disposal	
Distribution	Immediate customer	Business-to-business (B2B)	Business-to-consumer (B2C)		
Positive impacts	Dimension of positive impacts	Environmental	Economic	Social	
Negative impacts	Dimension of negative impacts	Environmental	Economic	Social	

Pair comparison of the alternatives in each criterion for each of the seven overarching BMCBEs

1 Optimising resource efficiency and use
2 Establishing biorefineries
3 Value recovery from waste
4 Resource (raw material and waste) exchange
5 Innovation towards bio- and renewable resources
6 Valuing the local economy
7 Service- and result-oriented offers

BMCBE - Business Model for a Circular Bioeconomy

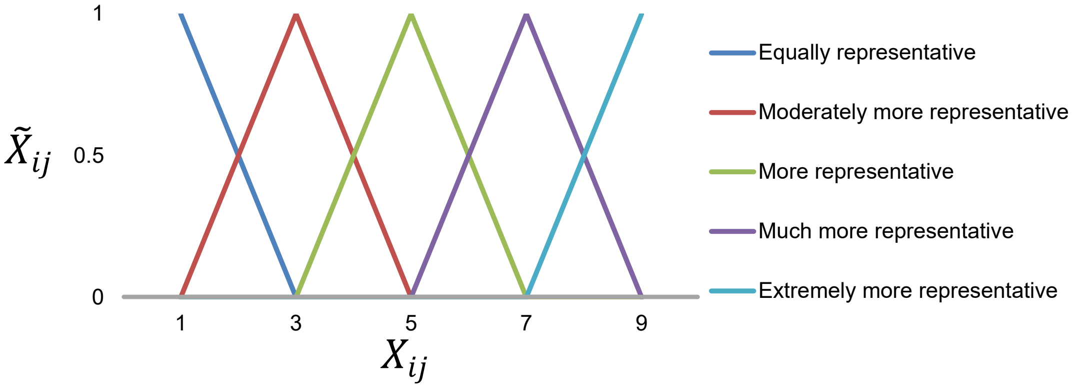
Source: Author (2021)

Definition 2: *Fuzzy number*. A fuzzy number is a number with an imprecise measurement, and it can be thought of as a function which domain is a set between 0 and 1 [0,1]. In a fuzzy number, a fuzzy interval in the real numbers, $\mathbb{R}$, is defined. A fuzzy interval is denoted as (l, m, u), i.e., the lower limit or the smallest possible value, l, the most probable value or the middle value, m, and the upper limit or largest possible value u. Therefore, a TFN can be described by $\tilde{A} = (l, m, u)$, with an MF such as in Eq. 1 (page 52):

$$\mu_A(x) = \begin{cases} 0, & x \leq l \\ \frac{x-l}{m-l}, & l < x \leq m \\ \frac{u-x}{u-m}, & m < x \leq u \\ 0, & x > u \end{cases} \qquad \textbf{Eq. 1}$$

In this study, the linguistic variables were defined as positive TFNs, as shown in Figure 10 (page 52), following Saaty's (1980) scale of pairwise comparisons. Moreover, Table 6 (page 52) shows the correspondence of each linguistic variable with its TFN and the crisp value of the variable in the 9-point scale, also accounting for the inverse (i.e., $\frac{1}{u}, \frac{1}{m}, \frac{1}{l}$) TFNs that lie on the other side of the scale, for when the attribute is less preferable or less important.

Figure 10 - Linguistic variables and triangular association function



Source: Author (2021)

Table 6 - Association between linguistic variable, triangular fuzzy number, and crisp value in a 9-point scale

Linguistic Variable	Triangular Fuzzy Number (l, m, u)	Crisp Value (9-point scale)
Extremely less representative	$\left(\frac{1}{9}, \frac{1}{9}, \frac{1}{8}\right)$	1
Much less representative	$\left(\frac{1}{8}, \frac{1}{7}, \frac{1}{6}\right)$	2
Less representative	$\left(\frac{1}{6}, \frac{1}{5}, \frac{1}{4}\right)$	3
Moderately less representative	$\left(\frac{1}{4}, \frac{1}{3}, \frac{1}{2}\right)$	4
Equally representative	$\left(\frac{1}{2}, 1, 2\right)$	5
Moderately more representative	$(2, 3, 4)$	6
More representative	$(4, 5, 6)$	7
Much more representative	$(6, 7, 8)$	8
Extremely more representative	$(8, 9, 9)$	9

Source: Author (2021)

For treating the data for each of the seven BMCBEs assessed in this research, every input (i.e., every judgement for how much more or less representative of the BMCBE one alternative was compared to the other, given a specific criterion), was fuzzified into a TFN (according to Table 6), and the set of inputs from each specialist was used to fill the values to the right of the diagonal (highlighted in bold in Eq. 2) of the fuzzy judgment matrix $\tilde{A}(a_{ij})$ as follows:

$$\begin{pmatrix} 1 & \boldsymbol{\tilde{a}_{12}} & \cdots & \boldsymbol{\tilde{a}_{1n}} \\ \tilde{a}_{21} & 1 & \cdots & \boldsymbol{\tilde{a}_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{pmatrix} \qquad \textbf{Eq. 2}$$

Having computed all entries from specialists, the operations to rank the alternatives using FAHP are described hereafter.

3.2.3.2Raking alternatives using FAHP

Let s be the total number of specialists, r be the total number of rows and c be the total number of columns in a matrix.

A matrix such as the one in Eq. 2 was built for every criterion being assessed within a BMCBE. After computing all the entries from all specialists as TFNs, the geometric mean of all the judgements from all specialists was calculated as the matrix $\widetilde{M}$, as seen in Eq. 3 (page 53):

$$\widetilde{M}_{ij} = \sqrt[s]{\prod_{n=1}^{n=s} \tilde{a}_{ijn}} \quad \forall i,j \qquad \textbf{Eq. 3}$$

As the calculations are conducted using fuzzy mathematics, the operations involving the fuzzy numbers are done such as with vectors, i.e., to obtain the geometric mean of fuzzy numbers, the lower values (l) are multiplied by one another and then the s^{th} root of that product is taken. The same is done with the middle values (m) and with the upper values (u).

Thereafter, one must calculate the geometric mean of each row in matrix $\widetilde{M}$, as in Eq. 4.

$$\tilde{Q}_i = \sqrt[c]{\prod_{j=1}^{c} \widetilde{M}_{ij}} \quad \forall i \tag{Eq. 4}$$

After that, the inverse values of $\tilde{Q}$ need to be determined, as in Eq. 5.

$$\widetilde{IQ}_i = \frac{1}{\tilde{Q}_i} \quad \forall i \tag{Eq. 5}$$

After calculating $\widetilde{IQ}_i$, the resulting values in the l, m, and u positions might not be in increasing order. Hence, one must order them placing the lowest value as (l), the middle value as (m), and the largest value as (u), thus obtaining $\widetilde{AIQ}_i$.

Thereafter, the values in $\tilde{Q}$ need to be normalised, by using Eq. 6.

$$\widetilde{W}_i = \tilde{Q}_i \otimes \widetilde{AIQ}_i \quad \forall i \tag{Eq. 6}$$

Then, the values of $\widetilde{W}$ must be deffuzified, using the center of area method (KAYA; AYCIN, 2021), as in Eq. 7.

$$D_i = \frac{l + m + u}{3} \quad \forall i \tag{Eq. 7}$$

After deffuzifying, the values in D need to be normalised, thus by using Eq. 8 (page 54).

$$ND_i = \frac{D_i}{\sum_{j=1}^{c} D_i} \quad \forall i \tag{Eq. 8}$$

The values in ND describe how representative the alternative i is within the criterion for a specific BMCBE. Lastly, the values in ND are multiplied by 9, to match the 9-point scale provided in the assessment, thus obtaining an adjusted vector AND (which will be later used in Stage IV).

3.2.3.3Determining the consistency of judgements

The consistency of judgements is based on the concept of transitivity, i.e., if a>b, and b>c, then a>c. To calculate the consistency ratio (CR), Eq. 9 is used.

$$CR = \frac{CI}{RI}$$ **Eq. 9**

Where,

CI = consistency index

RI = random consistency index

RI is obtained from Table 7, where n represents the dimension of the matrix.

Table 7 - Random consistency index

n	1	2	3	4	5	6	7	8	9
$\boldsymbol{RI}$	0	0.0001	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Source: Saaty (1980)

CI is calculated using Eq. 10.

$$CI = \frac{(\lambda_{max} - n)}{(n-1)}$$ **Eq. 10**

To obtain λ_{max} , firstly one needs to defuzzify $\widetilde{M}$ (which is the matrix with the geometric mean of the judgements from all specialists), once again using the centre of area method (see Eq. 7), thus obtaining M. Thereafter, M needs to be normalised, according to the total value of the columns, by using Eq. 11 (page 56).

$$NM_{ij} = \frac{M_{ij}}{\sum_{i=1}^{r} M_{ij}} \quad \forall i, j$$ **Eq. 11**

After normalising the values, the vector of weights is calculated by averaging the values in each row of NM, as in Eq. 12:

$$W_i = \frac{\sum_{j=1}^{c} NM_{ij}}{c} \quad \forall i$$ **Eq. 12**

Thereafter, the weighted sum value (WSV) needs to be calculated, by multiplying each element in the deffuzified matrix M by the element of W in the same position, as in Eq. 13:

$$WSV_i = \sum_{i=1}^{r} \sum_{j=1}^{c} (M_{ij} \times W_i) \quad \forall i$$ **Eq. 13**

Thereafter, the values for λ can be obtained by dividing WSV by W, as in Eq. 14.

$$\lambda_i = \frac{WSV_i}{W_i} \quad \forall i$$ **Eq. 14**

λ_{max} is the largest value found in λ, and should be used in Eq. 10, to calculate the CR. In case $CR \leq 0.1$, there are no inconsistencies, i.e., the judgements are acceptable, and the transitivity principle is being respected. However, in case $CR > 0.1$, judgements need to be revised.

All the procedures described in sections 3.2.3.2 and 3.2.3.3 were applied to each of the 19 criteria in a BMCBE, and then for each of the seven BMCBEs.

3.2.4 Delphi Study

The Delphi method aided Stages II and III of Phase II. The initial intent of the researcher was to conduct workshops where the assessments could be made in in-person meetings with an array of specialists.

However, due to the COVID-19 pandemic, the Delphi method was preferred, due to the possibility of conducting the assessments remotely and still maintaining scientific rigour by means of collecting expert opinions and taking into account the feedback from those experts.

Delphi is a group technique proposed by Dalkey and Helmer (1963), which aims to obtain the most reliable consensus among a group of experts or specialists, by means of a series of surveys or questionnaires using controlled feedback. Concisely, in a Delphi study, a group decision is achieved based on multiple rounds of questionnaires sent to a group of experts, where the responses are aggregated and shared with the group after each round (DELBECQ *et al*., 1975). That allows specialists to adjust their answers based on how they interpret the response of the group (MOKTADIR *et al*., 2019). Therefore, a Delphi study enables a true consensus among the experts in the group, which is typically reached in the second or third round (EMOVON *et al*., 2018). Regarding panel size, Clayton (1997) claims that 5-10 participants are enough if coming from a heterogeneous population, i.e., from different social/professional stratifications, and 15-30 if coming from a homogeneous population, whereas Hallowell and Gambatese (2010) state that 8-12 panellists is an ideal number of participants.

A Delphi study, thus, comprises (JIANG *et al*., 2022) (i) selecting specialists to take part in the assessment to be done, (ii) structuring a questionnaire to send to specialists to conduct the assessment, (iii) conducting a variable number of rounds of assessment, feeding information back to specialists until a group consensus is reached. The steps taken during the Delphi approach to this research are presented hereafter.

3.2.4.1Selecting specialists

The specialists selected to participate in the study were (i) the authors of the 19 journal articles in the Final Portfolio (ST2) from the SLR, (ii) the representatives of the 32 organisations contacted during the practise review, and (iii) specialists known by the researcher as having specialised knowledge on CBE and BMs, classified as other relevance (OR).

From SLR (i), in the 19 articles, 57 unique authors were identified, from which it was only possible to contact 46 of them, for reasons such as their email address not being found in publications or in open search engines, or an error message being returned when trying to send an email to the address found.

From PR (ii), the 32 organisations were represented by 31 individuals, since two organisations were represented by the same person.

For the group classified as OR (iii), 10 individuals from both academia and industry were listed. The distribution of invited specialists can be seen in Table 8.

Table 8 - Characteristics of invited specialists

Origin	From SLR (i)	From PR (ii)	From OR (iii)	Total
Academia	39	0	9	48
Industry	7	31	1	39

Source: Author (2021)

In total, 87 specialists were invited to participate in all rounds, being 55% of them from academia and 45% from industry.

3.2.5 Matching a Business Model with One of the BMCBEs - Stage IV

After profiling the seven BMCBEs, the results of the FAHP (presented later in Chapter 5) served as the basis for comparison with the BM of an organisation using the tool. The procedures for testing the tool are addressed in section 3.3. Nonetheless, the organisation using the tool will go through the same assessment as the seven BMCBEs, i.e., a profile of the organisation's BM is built using the 19 criteria, and the data treated using FAHP. To match the results of the organisation with the results of the seven BMCBEs, the distance between two points will be used to account for how distant the data from the organisation using the tool are from the data in each of the seven BMCBEs. The procedures to conduct this assessment are described hereafter.

The values of vector AND, resulting from the assessment of the BM of the organisation (for each criterion) using the tool (specific vector which will herein after be called BMO) will be compared to the values in AND in the profile of each one of the BMCBEs.

Let b be a BMCBE, j be a criterion, i be an alternative, and BMO be the vector (AND) containing the results of the organisation using the tool for the criterion. Using Eq. 15 one should calculate the Euclidean distances (KHAIRI *et al.*, 2021) between the results of BMO and those of each of the BMCBEs (and their respective AND vector) for all the alternatives in the criterion.

$$ED_{ijb} = \sqrt[2]{(BMO_i - AND_i)^2} \quad \forall j, b \qquad \textbf{Eq. 15}$$

Thereafter, the sum of all Euclidean distances from the 19 criteria, when comparing the results of each of the alternatives in BMO and the seven BMCBEs will be aggregated in vector SED, using Eq. 16.

$$SED_b = \sum_{j=1}^{c} \sum_{i=1}^{r} ED_{ijb} \quad \forall b \qquad \textbf{Eq. 16}$$

Lastly, to suggest a BMCBE for the organisation using the tool, a comparison will be made between the results of the organisation's BM and the results for each of the seven BMCBEs. The BMCBE with the lowest SED will be suggested to be pursued by the organisation, which will mean that it is the one closest to what was reported by the organisation when going through the 19 criteria.

3.3 METHODS FOR TESTING THE TOOL - PHASE III

Testing the tool comprised selecting an organisation for the tests, troubleshooting of the tool via its use for testing, and thus conducting a case study to show its validity.

3.3.1 Selecting an Organisation and Making use of the Tool

An organisation to test the tool and build a case study was selected by convenience sampling. A BE start-up that has initiated its activities in the same campus of the university where the researcher works was invited to be the first user of the tool.

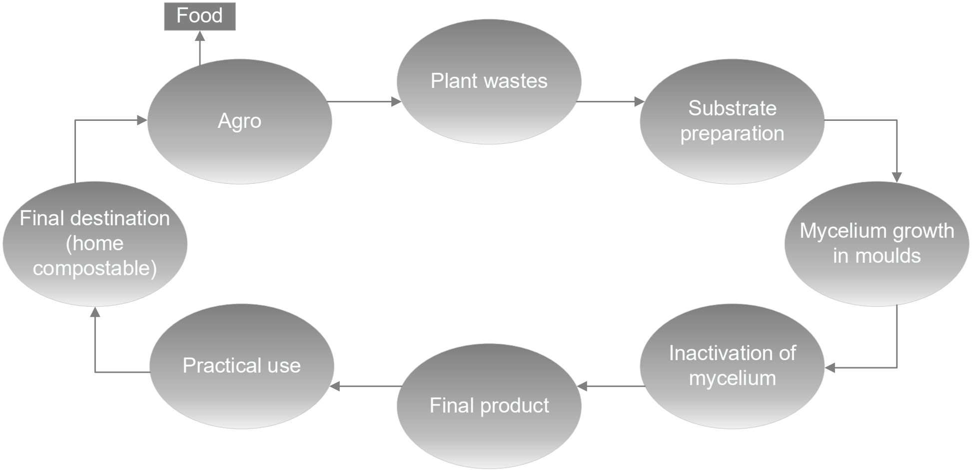
The organisation is located in Brazil, in the state of Paraná, operate in a BE context, and their main product is a thermo-acoustic panel made from agricultural wastes. This organisation is hereinafter called Organisation X.

3.3.2 Case Study + Troubleshooting

The testing of the tool resulted in the first case study for which the tool provided results. The case study was conducted to ensure the validity of the tool and to investigate aspects of its use. The case study was conducted assessing the opportunities for a BMCBE in a BE start-up who develops solutions in the decoration, civil construction, and packaging sectors, by producing fungi-based products and making use of agricultural waste as their main feedstock.

Organisation X already develops its activities in the realm of the CBE. Nonetheless, they were interested in further opportunities that could be taken based on their existing BM to improve their performance across the environmental and business dimensions. The current workflow for Organisation X's thermo-acoustic panel made from biowastes can be seen in Figure 11.

Figure 11 - Workflow system of Organisation X for producing thermo-acoustic panels



Source: Information provided by Organisation X

The system under which Organisation X works already enables a certain degree of circularity. It starts with the use of plant waste, especially agricultural wastes as feedstock to the thermo-acoustic panel. They add mycelium and a few other inputs to this feedstock and the mix is enclosed in moulds for the mycelium to grow. The mycelium grows up to a certain point and then it is inactivated by a thermal treatment.

At this point, the final product (thermal-acoustic panel in the desired size and shape, according to the moulds used) is obtained. The panel can have a range of practical uses, which is left at the end user's discretion. At the end-of-life, the panels are compostable, which can be done either at home (e.g., in a garden or as feed for flowers even in small vases) or in any other earth-environment. As they do not make use of any toxic chemicals, it is safe to be used as an input for agro-systems, which wastes can then be once again used as feedstock to produce new panels.

For the B2Circle tool to be used to suggest a BMCBE to Organisation X, two official meetings took place. The first meeting was held online and lasted approximately 30min. During this meeting, the researcher gave an overview of the intent of the tool and explained how the assessment would happen, presented the structure of the Circular Canvas and the criteria under which the organisation's BM would be assessed, and told the organisation's representatives that they would be required to make pair-comparisons between every two alternatives in each criterion according to what represented best Organisation X's BM. Two members of Organisation X participated in the meeting and went through the pair comparisons necessary to profile the BM of the organisation. The process was guided by the researcher, who filled out the information in a spreadsheet prepared as a pilot of the tool. After the meeting the researcher analysed the data and noticed inconsistencies in the assessment (as per the CR of the FAHP), which called for a second meeting to resolve the inconsistencies.

The second meeting was held in person at the Sustainable Production Systems Laboratory (LESP) at the Ponta Grossa Campus of the Universidade Tecnológica Federal do Paraná (UTFPR), for which all the necessary sanitary measures were taken. The researcher and one representative from Organisation X participated in this meeting. During the second meeting, the researcher and the company representative went through the sources of inconsistencies and sorted them out until both the assessment had no inconsistencies and the profile built for Organisation X fairly represented the BM in practise by them. The second meeting lasted approximately 30min. Thereafter, the researcher treated and analysed the data.

Afterwards, a third meeting was arranged, which also took place at LESP, where the researcher and one representative from Organisation X participated. This third meeting served the purposes of presenting the initial results provided by the tool and summarised by the researcher, and acquiring initial feedback on the results provided.

Thereafter, the researcher analysed the results in greater depth and built the recommendations to Organisation X according to the results provided by the B2Circle tool. A summary of the results and recommendations were sent to the representatives of Organisation X by email in the form of a technical report. Later, a fourth meeting with four representatives from Organisation X took place, where the researcher presented the final results and recommendations and discussed them with Organisation X's representatives.

Besides those four meetings, a series of small conversations and meetings (in-person, via video calls, emails and other written communication means) occurred between the researcher and different representatives from Organisation X in order for the researcher to acquire knowledge on the product system (thermoacoustic panels) and to conduct the Life Cycle Assessment (LCA) (presented later in section 6.2, as part of the recommendations made to Organisation X).

This stage also comprised the testing of the proposed tool for troubleshooting, both during its development and structuring and during its testing/first use. At this stage the researcher sought to spot any adjustments deemed necessary regarding methodological procedures or operational activities comprising the use of the tool and calculations. An issue identified by the researcher thus far which needed to be dealt with in troubleshooting was the interface of the tool.

The pilot of the tool was built using Excel. At first the researcher had established an interface much similar to what was used in the calculations and the running of the tool. However, it was deemed by the researcher to be visually polluted and heavy, thus the researcher redeveloped it to show the 9-point scale on top, and the pair-comparisons below (with the rows of the scale frozen so that the user could always refer to the scale for all comparisons), where the column to be filled out with the linguistic variables was highlighted. Further issues might (and much likely will) appear when the tool grows out of its pilot version.

4 RESULTS AND DISCUSSIONS FROM THE LITERATURE AND PRACTISE REVIEWS - PHASE I

BMCBEs are BMs that enable the production, use, and management of bioresources aiming to make products with the highest added value at every cycle, in a cascaded use and upcycling whenever possible, and seeking to close, slow, or narrow resource flows and reduce material leakage. Given this perspective, this Chapter starts presenting the findings of the present dissertation (covering specific objective i), which will assist building the proposed tool. Unveiling the barriers, challenges, drivers, and opportunities for businesses in a CBE allowed the researcher to explore the universe of the CBE from a business perspective and helped explore the needs and desires of different businesses, as well as their difficulties and the strategies they had to unfold in order to overcome hardships, which yielded high-level intelligence and lessons to be shared with the researcher.

4.1 BARRIERS, CHALLENGES, DRIVERS AND OPPORTUNITIES FOR BUSINESSES IN A CIRCULAR BIOECONOMY

The barriers, challenges, drivers, and opportunities presented in this section comprise, rather than a mere report of what has been found in the existing research and practise, a synthesis of the literature consulted by the authors, coupled with a critical view of the role of each of these factors (barriers, challenges, drivers, and opportunities) for businesses to advance a CBE, and count on the practical perspectives of the individual organisations, research institutes, and collective organisations interviewed.

4.1.1 Barriers in a Circular Bioeconomy

For the purposes of this research, barriers are considered forces that are already in place and prevent the implementation of CBE practises (e.g., lack of technically and/or economically feasible technology to preserve a certain bioresource during long-distance travelling), making businesses having to “go around” them. The main barriers are summarised in Table 9 (page 64) and detailed thereafter.

Table 9 - Barriers in a circular bioeconomy

ID	Factor	Supporting literature	Number of mentions from interviews (n=32)
B-1	transportation/logistics costs and management	Awasthi *et al*. (2020); Banu *et al*. (2020a); Cheng *et al*. (2020); Donner *et al*. (2020); Donner *et al*. (2021); Duan *et al*. (2020); Duque-Acevedo *et al*. (2020b); Egelyng *et al*. (2018); Hagman *et al*. (2019); Jarre *et al*. (2020); Kumar and Verma (2021); Loizides *et al*. (2019); Pan *et al*. (2021); Salvador *et al*. (2021c); Sandvold *et al*. (2019); Stegmann *et al*. (2020); WBCSD (2019)	6
B-2	limitations on infrastructure and storage capabilities	Banu *et al*. (2020a); D'Amato *et al*. (2020); Donner *et al*. (2020); Donner *et al*. (2021); Duan *et al*. (2020); Falcone *et al*. (2020); Gottinger *et al*. (2020); Imbert (2017); Mehta *et al*. (2021); Salvador *et al*. (2021c)	5
B-3	lack of knowledge on valorisation pathways	Banu *et al*. (2020b); Barcelos *et al*. (2021); Catone *et al*. (2021); Klitkou *et al*. (2019); D'Amato *et al*. (2020); Kapoor *et al*. (2020); Temmes and Peck (2020)	5
B-4	lack of financial resources/capital	Angouria-Tsorochidou *et al*. (2021); Awasthi *et al*. (2019); Banu *et al*. (2020); Barcelos *et al*. (2021); D'Amato *et al*. (2020); Donner *et al*. (2021); Duan *et al*. (2020); Goswami *et al*. (2021); Gottinger *et al*. (2020); Gregg *et al*. (2020); Jesus *et al*. (2021); Kang *et al*. (2020); Kapoor *et al*. (2020); Kokkinos *et al*. (2020); Liu *et al*. (2021); Morone and Imbert (2020); Näyhä (2020); Puyol *et al*. (2017); Sarma *et al*. (2021); Ubando *et al*. (2020)	14
B-5	overregulation or inadequate regulation	Berbel and Posadillo (2018); Donner *et al*. (2021); Duque-Acevedo *et al*. (2020a); Falcone *et al*. (2020); Gottinger *et al*. (2020); Imbert (2017); Kapoor *et al*. (2020); Hadley Kershaw *et al*. (2021); Ladu *et al*. (2020); Mak *et al*. (2020); Marcinek and Smol (2020); Morone and Imbert (2020); Santagata *et al*. (2021)	7
B-6	lack of demand-pull effect	Imbert (2017); Stegmann *et al*. (2020)	5
B-7	cultural unfitness	Klitkou *et al*. (2019); Mikielewicz *et al*. (2020); Morone and Imbert (2020); Salvador *et al*. (2021c)	3
B-8	seasonality of feedstock	Donner *et al*. (2020); Salvador *et al*. (2021c)	2
B-9	(partial) lack of governmental support	Awasthi *et al*. (2019); Barcelos *et al*. (2021); Brandao *et al*. (2021); Donner *et al*. (2021); Duan *et al*. (2020); Jarre *et al*. (2020); Kapoor *et al*. (2020); Kit Leong *et al*. (2021); Mikielewicz *et al*. (2020); Mohan *et al*. (2018); Negi *et al*. (2021); WBCSD (2019)	6

Source: Author (2021)

B-1: transportation/logistics costs and management. Transport is an issue of concern due to economic feasibility. Costs of logistics might affect the economy, and it has been widely stressed that logistical improvements by all parties, but mainly the valuation of the local economy, should be targeted.

B-*2: limitations on infrastructure and storage capabilities*. Limitations on infrastructure and storage capabilities are considered a barrier, since bioresources in general tend to perish or decompose more quickly than non-bio-based ones if not given adequate care. Improved logistics, storage, and maintenance processes would also mitigate the impacts of fluctuation in volumes of resources, and thus product outputs. Therefore, storage capabilities might need extra investments.

B-3: lack of knowledge on valorisation pathways. Alternate handling or trading of resources and waste seems many times prevented due to lack of knowledge to develop creative and operable solutions, as well as the perception of efforts necessary for such change, including time, behavioural and cultural changes, and the costs involved.

B-4: lack of financial resources/capital. The lack of financial capital regards both private investors wanting to invest in such businesses, and incentives from governments. Companies that want to pursue new businesses or try to establish new valorisation pathways might lack the resources needed to invest in infrastructure, new technologies (either for development or acquisition) and overheads, especially regarding implementation costs, which might be high when/if transitioning to entirely new operations.

B-5: overregulation or inadequate regulation. Policies to reduce waste tend to increase the costs of this raw material in the future CBE. Moreover, most countries that have policies to support BE have focused on least preferred bioenergy and biofuels, which provide the lowest value-added strategies.

*B-6: lack of demand-pull effect***.** Lack of a demand-pull effect might also prevent bio-products from reaching the market.

*B-7: cultural unfitness***.** A company might have a culture that will not allow, or will make it difficult, for a transition to a new or adapted business that fits the CBE.

B-8: seasonality of feedstock. Different types of feedstocks might be available only seasonally, which might force a company to plan having a portfolio of products that account for such fact or, for instance, develop and establish adequate storage facilities and processes to be able to cope with constant demand and supply.

B-9 (partial) lack of governmental support. There seems to be a lack of governmental support in some regions, regarding political and financial incentives or subsidies for businesses to engage in and/or maintain BE-based practises. There are regional and national differences concerning this issue, and not all valorisation pathways are equally supported. In Europe, for instance, biogas production at times strongly profits from public subsidies and governmental support.

4.1.2 Challenges in a Circular Bioeconomy

For the purposes of this research, challenges are considered forces that make the implementation of CBE practises more difficult (e.g., lack of governmental support), making businesses spend more resources/effort in overcoming them. The main challenges are synthesised in Table 10 (page 67) and discussed hereafter.

C-1: scaling-up. Many BE products still lack sufficient value generation and thus large-scale commercialisation, hence being only prototypes.

C-2: maintaining a uniform product. One of the risks of valorising bioresources lies on its supply. As they might depend on the by-products or wastes from other processes or industries, it is difficult to ensure a continuous flow or even the same mix and quality, which calls for physical requirements and might make it difficult to maintain product uniformity.

C-3: motivating production of low-priced products. In a cascaded system, if one alternative use, even though lower in the value chain, seems attractive, it can avoid the production of an alternative product that is higher in the value chain but seems more costly. Additionally, wastes tend to be bulky, thus having a low value per ton.

C-4: need of investments to integrate biorefineries. Many times, considerable investments might be needed to integrate biorefineries and establish partnerships that would allow cleaner and of higher value paths.

C-5: finding/unveiling market demand for bio-based products. Finding or unveiling market demand for bio-based products might sometimes mean creating new market segments.

Table 10 - Challenges in a circular bioeconomy

ID	Factor	Supporting literature	Number of mentions from interviews (n=32)
C-1	scaling-up	Awasthi *et al*. (2019); Behera *et al*. (2021); Chandrasekhar *et al*. (2020); Donner *et al*. (2020); Donner *et al*. (2021); Gregg *et al*. (2020); Kumar and Verma (2021); Yi Leong *et al*. (2021); Nagarajan *et al*. (2020); Reim *et al*. (2019); Santagata *et al*. (2021); Usmani *et al*. (2021)	9
C-2	maintaining a uniform product	Awasthi *et al*. (2019); Donner *et al*. (2020); Jarre *et al*. (2020); Marcinek and Smol (2020); Morone and Imbert (2020)	0
C-3	motivating production of low-priced products	Donner and de Vries (2021); Hagman *et al*. (2019)	0
C-4	need of investments to integrate biorefineries	Barros *et al*. (2020); Clauser *et al*. (2021); Gyalai-Korpos *et al*. (2018); Jain *et al*. (2022); Marcinek and Smol (2020); Qin *et al*. (2021); Yi Leong *et al*. (2021); Stegmann *et al*. (2020); Temmes and Peck (2020); Tsegaye *et al*. (2021)	2
C-5	finding/unveiling market demand for bio-based products	D'Amato *et al*. (2020); Gottinger *et al*. (2020); Gyalai-Korpos *et al*. (2018); Stegmann *et al*. (2020)	9
C-6	guaranteeing sustainability and security of biomass supply in the long term	Donner *et al*. (2021); Gyalai-Korpos *et al*. (2018); Menon and Lyng (2021); Muscat *et al*. (2021); Salvador *et al*. (2021c)	3
C-7	lack of public/consumer awareness	Barcelos *et al*. (2021); Donner and de Vries (2021); Donner *et al*. (2021); Duan *et al*. (2020); Egelyng *et al*. (2018); Gottinger *et al*. (2020); Gregg *et al*. (2020); Jarre *et al*. (2020); Ladu *et al*. (2020); Mak *et al*. (2020); Marcinek and Smol (2020); Mikielewicz *et al*. (2020); Salvador *et al*. (2021c); WBCSD (2019)	11
C-8	economic competitiveness among recovery alternatives might affect cascading	Jarre *et al*. (2020)	3
C-9	consumer willingness to buy products of non-primary cycles	Donner *et al*. (2021); Jarre *et al*. (2020)	5
C-10	company size	Bolwig *et al*. (2019); Donner *et al*. (2020); Näyhä (2020)	1

ID	Factor	Supporting literature	Number of mentions from interviews (n=32)
C-11	collaboration	Barros *et al*. (2020); Brandao *et al*. (2021); Donner *et al*. (2021); Falcone *et al*. (2020); Gottinger *et al*. (2020); Negi *et al*. (2021); Sandvold *et al*. (2019); Temmes and Peck (2020); Santagata *et al*. (2021)	9
C-12	price competitiveness	Donner *et al*. (2021); Solis *et al*. (2020)	14
C-13	final product quality/efficiency	Cheng *et al*. (2020); Parthasarathy and Narayanan (2014)	0
C-14	lack of knowledge/skills/competencies	Gottinger *et al*. (2020); Falcone *et al*. (2020); Hagman *et al*. (2019); Kapoor *et al*. (2020); Negi *et al*. (2021)	4
C-15	product portfolio of biorefineries might vary over time	Donner *et al*. (2020); Hagman *et al*. (2019); Tsegaye *et al*. (2021)	1
C-16	lack of adequate technology	Awasthi *et al*. (2019); Awasthi *et al*. (2020); Barros *et al*. (2020); Barcelos *et al*. (2021); D'Amato *et al*. (2020); Donner and de Vries (2021); Donner *et al*. (2021); Duan *et al*. (2020); Falcone *et al*. (2020); Kapoor *et al*. (2020); Hadley Kershaw *et al*. (2021); Yi Leong *et al*. (2021); Liu *et al*. (2021); Marcinek and Smol (2020); Menon and Lyng (2021); Mohan *et al*. (2016); Mohan *et al*. (2018); Morone and Imbert (2020); Sandvold *et al*. (2019); Santagata *et al*. (2021); Sarma *et al*. (2021); WBCSD (2019)	11
C-17	lack of standardisation of inputs	Donner *et al*. (2021); Jarre *et al*. (2020); Maina *et al*. (2017); Marcinek and Smol (2020); Morone and Imbert (2020)	0
C-18	lack of regulations and policies to promote environmentally sound product design	Bio-Based Industries Consortium, (2012); Gottinger *et al*. (2020); Jarre *et al*. (2020); Maina *et al*. (2017); Stegmann *et al*. (2020)	7
C-19	lack of incentive for upcycling	Donner *et al*. (2020); Egelyng *et al*. (2018); Jarre *et al*. (2020); Stegmann *et al*. (2020); Temmes and Peck (2020)	3

Source: Author (2021)

C-6: guaranteeing sustainability and security of biomass supply in the long term. Related to C-2, relying on by-products or wastes from other processes or industries, might pose a threat to a continuous flow and sustainable procurement of a certain resource or material. Therefore, securing a continuous and sustainable supply of bioresources might require great involvement, engagement, and proximity from biomass suppliers and/or other industries.

C-7: lack of public/consumer awareness. Consumer awareness (and many times behavioural change) is necessary to attract the due attention to products of a BE. It tackles the knowledge or attention that customers might lack regarding products from bio-sources or reclaimed materials. Lack of public awareness of bio-based products and its advantages and benefits might disrupt their presence in the market.

C-8: economic competitiveness among recovery alternatives might affect cascading. Economic competitiveness among different alternatives for cascading might make resources soon reach an alternative from which they can no longer be recovered, thus reducing the life of the resource within the technical system.

C-9: consumer willingness to buy products of non-primary cycles. Linked to the issue of consumer awareness, consumers might avoid (for a number of reasons) products that are made from non-virgin materials.

C-10: company size. One the one hand, large companies are not necessarily resistant to change, but they might lack the required dynamic capability; they lack knowledge, most of the time, of the end user of their products, making their strategy definition difficult. Small companies, on the other hand, consider themselves too small to uptake the complications and costs of pursuing new paths.

C-11: collaboration. For valorising biomass, there is an increased need for (cross-sector, private-private, and public-private) collaboration, e.g., for reaching new markets, joint investments, economies of scale, and knowledge exchange.

C-12: price competitiveness. Difficulty in competing in a market with cheaper products based on fossil resources - especially fuels.

C-13: quality/efficiency of final product. The quality or efficiency of products derived from bioresources might be perceived as lower than those of fossil/non-renewable resources, which can be the case of fuels. This might pose a challenge for society to switch to bio-based products altogether.

C-14: lack of knowledge/skills/competencies. Firms might be reluctant to go into new business areas for valorisation of waste because optimised use or recovery of the resource/material is outside the company's core business. Moreover, and therefore, they might lack specific knowledge, or skills, or competency to manage the related operations.

C-15: product portfolio of biorefineries might vary over time. As it might be difficult to maintain the same mix and volume of inputs, the end products of biorefineries might vary from time to time. Therefore, for them to succeed and secure revenue, it might be necessary to maintain an array of products and perhaps large inventories of final products (when possible) to maintain steady demand and offer.

C-16: lack of adequate technology. This has been given a warm discussion, both regarding the existing technology that already allows taking better advantage of available bio-resources and bio-waste; however, it seems that overall technology might be immature yet, there being much more to be done in the near future and in the long term if the BE is to gain greater momentum. There is a need for adequate technologies, which are required to be economically feasible on top of being technically possible and to focus on enabling recovery rather than “separation for disposal”.

C-17: lack of standardisation of inputs. As many products in the BE originate from wastes from other processes/companies/sectors, one greater barrier for the commercialisation of such products is that the inputs used might vary significantly (e.g., for every batch), making it difficult to maintain quality standards.

C-18: lack of regulations and policies to promote environmentally sound product design. Linked to the lack of governmental support, there appears to be little to no specific regulations or policies seeking to promote environmentally sound product design via a BE. One of the leading initiatives, though, comes from the European Commission, who has launched a joint undertaking between industry and the public sector for bio-based industries (BIO-BASED INDUSTRIES CONSORTIUM, 2012).

C-19: lack of incentive for upcycling. There is lack of specific incentives/policies promoting and sustaining the use of a resource, and economic incentives or opportunities, or support for pursuing more value-added alternatives instead of cascading down.

To overcome the range of barriers and challenges that permeate the implementation and management of a CBE, one can make sense of its drivers.

4.1.3 Drivers in a Circular Bioeconomy

For the purposes of this research, drivers are considered forces that are known to be contributors to facilitating or accelerating the implementation of CBE practises. Drivers might already be in place or not, i.e., they can already exist (e.g., policies) or not (e.g., technological advancement that would allow processing a certain resource into marketable products). The drivers are listed in Table 11 (page 72).

D-1: alleviating resource supply risks. A CBE helps alleviate the risk of resource supply by enabling a shift from non-renewable resources (e.g., fossil fuels) promoting the use of biomass which is renewable and more sustainable.

D-2: reduction of material leakage. The search for reducing material leakage out of the technical system is of utmost importance for a CBE. This means preventing whenever and wherever possible that waste be disposed of into the natural environment.

D-3: more efficient resource use. An efficient use of resources enables optimising the extraction and use of resources, causing them to cycle for longer, and, consequently, reducing the pace of their leakage out of the system. On top of that, greater efficiency in the use of resources might also mean lower costs or higher profits for companies.

D-4: designing out waste. Another driver of a CBE is designing how waste will leave the system, even before its generation. This calls for resilient systems that enable strategizing a waste hierarchy throughout multiple cycles and making waste streams that leave the technical system (into the natural environment) as harmless as possible.

D-5: circular systems that support revenue streams. No business will succeed if there is no stream of revenue. Therefore, it is required that CBE systems and BMs support one or a set or revenue streams, proving their financial feasibility. One benefit of, for instance, waste-based biorefineries is that “waste feedstock”, at times, can help balance the initial investments, if it would be the case.

D-6: technological advancement. Technological advancement is another critical factor driving the transition to a CBE. Technologies that allow getting the most value from resources at the lowest cost are preferable. In addition, it should be given priority to technologies that focus on material recovery instead of removal or separation.

Table 11 - Drivers in a circular bioeconomy

ID	Factor	Supporting literature	Number of mentions from interviews (n=32)
D-1	alleviating resource supply risks	Lange *et al*. (2021); WBCSD (2019)	5
D-2	reduction of material leakage	Awasthi *et al*. (2019); Dahal *et al*. (2018); Zecevic *et al*. (2019)	6
D-3	more efficient resource use	Awasthi *et al*. (2019); Barros *et al*. (2020); Duque-Acevedo *et al*. (2020b); Hagman and Feiz (2021); Sadhukhan *et al*. (2020); Zecevic *et al*. (2019)	7
D-4	designing out waste	Awasthi *et al*. (2019); Barros *et al*. (2020); Lybæk and Kjær (2021)	6
D-5	circular systems that support revenue streams	Santagata *et al*. (2021); Salvador *et al*. (2021c); Zecevic *et al*. (2019)	6
D-6	technological advancement	Awasthi *et al*. (2019); Barros *et al*. (2020); Gregg *et al*. (2020); Kapoor *et al*. (2020); Kardung *et al*. (2021); Mikielewicz *et al*. (2020); Pan *et al*. (2021); Puyol *et al*. (2017); Salvador *et al*. (2021c); Sherwood (2020);	6
D-7	competitive advantage	Banu *et al*. (2020b); Barros *et al*. (2020); WBCSD (2019)	11
D-8	innovation	Barcelos *et al*. (2021); Bugge *et al*. (2019); Chowdhary *et al*. (2021); Donner *et al*. (2020); Falcone *et al*. (2020); Gregg *et al*. (2020); Hansen (2016); Ladu *et al*. (2020); Kit Leong *et al*. (2021); Mikielewicz *et al*. (2020); Näyhä (2020); Reim *et al*. (2019); Salvador *et al*. (2021c); UNEP (2017)	5

ID	Factor	Supporting literature	Number of mentions from interviews (n=32)
D-9	establishment of collaborations and networks	Awasthi *et al*. (2019); Barcelos *et al*. (2021); Barros *et al*. (2020); Bolwig *et al*. (2019); D'Amato *et al*. (2020); Donner and de Vries (2021); Donner *et al*. (2021); Egea *et al*. (2018); Kapoor *et al*. (2020); Johnson *et al*. (2021); Kardung *et al*. (2021); Marcinek and Smol (2020); Näyhä (2020); Näyhä and Pesonen (2014); Salvador *et al*. (2021c); Santagata *et al*. (2021); Toppinen *et al*. (2017); UNEP (2017)	12
D-10	open, environment-driven culture	Angouria-Tsorochidou *et al*. (2021); Björkdahl and Börjesson (2011); Gottinger *et al*. (2020); Näyhä (2020)	4
D-11	establishment of public policies/governmental support	Angouria-Tsorochidou *et al*. (2021); Barcelos *et al*. (2021); Brandao *et al*. (2021); Gregg *et al*. (2020); Imbert (2017); Johnson *et al*. (2021); Kardung *et al*. (2021); Kleinschmit *et al*. (2014); Yi Leong *et al*. (2021); Mak *et al*. (2020); Tsai and Lin (2021)	18
D-12	research and development	Behera *et al*. (2021); Bugge *et al*. (2019); Donner *et al*. (2021); Kapoor *et al*. (2020); Salvador *et al*. (2021c); UNEP (2017)	3
D-13	waste management regulation	Angouria-Tsorochidou *et al*. (2021); Barros *et al*. (2020); Donner and de Vries (2021)	2
D-14	new business models	Donner *et al*. (2020); Barcelos *et al*. (2021); Barros *et al*. (2020); DeBoer *et al*. (2020); Duque-Acevedo *et al*. (2020b); Egea *et al*. (2018); Mehta *et al*. (2021); Salvador *et al*. (2021c)	7
D-15	products with potentially lower environmental impacts	Banu *et al*. (2020a); Banu et al. (2020b); Barcelos *et al*. (2021); Barros *et al*. (2020); Bos and Broeze (2020); Cheng *et al*. (2020); DeBoer *et al*. (2020); Duque-Acevedo *et al*. (2020b); Goswami *et al*. (2021); Hagman *et al*. (2019); Johnson *et al*. (2021); Kang *et al*. (2020); Kokkinos *et al*. (2020); Kumar and Verma (2021); Kit Leong *et al*. (2021); Nagarajan *et al*. (2020); Paredes-Sánches *et al*. (2019); Puyol *et al*. (2017); Rekleitis *et al*. (2020); Santagata *et al*. (2021); Stegmann *et al*. (2020)	11

Source: Author (2021)

D-7: competitive advantage. Increased competitive advantage can be achieved via the offer of products with lower environmental impacts when compared to traditional products. Competitive advantages can also be achieved by taking better advantage of by-products/wastes and turning them into a new revenue stream.

D-8: innovation. Innovation can be technology or business-related. Some companies might be innovative in manufacturing, but not as much in product and business systems, which are crucial for the transition to a CBE.

D-9: establishment of collaborations and networks. Organisational innovation is necessary, which calls for different kinds of expertise, as well as the establishment of collective efforts through cooperative organisations and networks, and the creation of consortia, for businesses to seize the benefits of collective efforts. Cooperative organisations (as providers of raw material, investors, or end-users) can ease the commercialisation of technologies, as well as help mitigate impacts. On a tactical and operational level, it can be highlighted the advantage of having integrated biorefineries that allow producing a range of products. On a more strategic approach, one can mention the use of joint ventures for the valorisation of waste, as well as co-creation and joint R&D.

D-10: open, environment-driven culture. Another crucial aspect is a company's culture, as it needs to allow for the necessary changes to be able to incorporate the aspects of a CBE, whereby support from top management can be decisive to innovation. It requires a culture holding both willingness and belief in change. The commitment to an environment-driven conduct could also benefit a CBE.

D-11: establishment of public policies/governmental support. The transition to a BE, as an emerging sector, could benefit from public policies from both demand and supply sides. The role of the government, working out regulations, and the existence of political initiatives allow for a shift towards a CBE.

D-12: research and development. The work of research institutions, and of private companies on innovation through scientific discoveries and their commercialisation also drive a CBE.

D-13: waste management regulation. As addressed in B-5 and C-18, the lack of, excess of, or inadequate regulation might be barriers or pose challenges for a CBE, but when the correct regulations (e.g., for waste management) are in place, they can act as drivers of it. One cannot be certain yet of what the most adequate regulations for a CBE are, though.

D-14: new business models. Another driver lies in the willingness to invest in new BMs, powered by the perception of new business opportunities, new markets, and the pressure for transitioning to a more sustainable and circular business conduct.

D-15: products with potentially lower environmental impacts. Mainly (but not only) from waste, bioresources bring options with some of the lowest environmental impacts. Greatly due to the use of renewable resources, it can be observed reductions of emissions of GHG (for instance), hence mitigating the effects of global warming, which has been a severe global concern in the last few decades, along with other concerns regarding planetary boundaries.

4.1.4 Opportunities in a Circular Bioeconomy

For the purposes of this research, opportunities are considered aspects and/or situations that are already in place and can be taken advantage of to enable implementing CBE practises (e.g., locally available biomass feedstock). A series of opportunities for a CBE are listed in Table 12 (page 76).

O-1: turning waste into bioproducts. In a CBE, there is the possibility of creating several bioproducts from waste, which would otherwise have been disposed of in a less environmentally friendly way and losing their added value.

O-2: bioenergy production. One of the main paths for the use of bioresources seems to have been the production of energy, mainly via the use of organic waste and consequent reduction of environmental impacts. There remain sufficient opportunities for agriculture in the bioenergy sector, in particular via the utilisation of agricultural waste and by-products as well as by harvesting energy crops, thus powering the substitution of non-renewable energy sources. Moreover, also waste and by-product streams from the food and forestry industries, black liquor from the paper industry, can be used for thermal and electrical energy. The bioenergy sector seems to contribute to (i) a decrease in GHG emissions, along with the reduction of risks of environmental damages; (ii) less pressure on non-renewable resources and their energy dependence, and (iii) employment in rural areas by the bioenergy industry.

Table 12 - Opportunities in a circular bioeconomy

ID	Factor	Supporting literature	Number of mentions from interviews (n=32)
O-1	turning waste into bioproducts	Awasthi *et al*. (2020); Barcelos *et al*. (2021); Barros *et al*. (2020); Coppola *et al*. (2021); Dahal *et al*. (2018); Duan *et al*. (2020); Kardung *et al*. (2021); Yi Leong *et al*. (2021); Maina *et al*. (2017); Nagarajan *et al*. (2020); Santagata *et al*. (2021); Sadhukhan *et al*. (2020); Sharma *et al*. (2021); WBCSD (2019)	11
O-2	bioenergy production	Amit *et al*. (2021); Awasthi *et al*. (2019); Awasthi *et al*. (2020); Banu *et al*. (2020b); Barcelos *et al*. (2021); Barros *et al*. (2020); Bian *et al*. (2020); Clauser *et al*. (2021); Donner and Radic (2021); Duan *et al*. (2020); Duarte *et al*. (2021); Duque-Acevedo *et al*. (2020b); Kang *et al*. (2020); Kapoor *et al*. (2020); Kaszycki *et al*. (2021); Kit Leong *et al*. (2021); Liu *et al*. (2021); Lybæk and Kjær (2021); Lybæk and Kjær (2022); Madadian *et al*. (2021); Moreira *et al*. (2021); Muscat *et al*. (2021); Paredes-Sánches *et al*. (2019); Puyol *et al*. (2017); Rekleitis *et al*. (2020); Santana *et al*. (2021); Sefeedpari *et al*. (2020); Sharma *et al*. (2021); Sherwood (2020); Temmes and Peck (2020); Tsai and Lin (2021); Vanhamäki *et al*. (2019); WBCSD (2019); Zecevic *et al*. (2019)	11
O-3	lower production costs when using bioresources/biowaste	Banu *et al*. (2020b); Kang *et al*. (2020); Yi Leong *et al*. (2021); Vea *et al*. (2018)	3
O-4	waste recovery	Awasthi *et al*. (2020); Barros *et al*. (2020); Chandrasekhar *et al*. (2020); Coppola *et al*. (2021); Dahal *et al*. (2018); Dahiya *et al*. (2018); Donner and Radic (2021); Donner *et al*. (2020); Duque-Acevedo *et al*. (2020a); Gregg *et al*. (2020); Kapoor *et al*. (2020); Kwan *et al*. (2018); Lange *et al*. (2021); Loizides *et al*. (2019); Mpofu *et al*. (2021); Overturf *et al*. (2020); Pagliaro (2020); Rekleitis *et al*. (2020); Sefeedpari *et al*. (2020); Tsai and Lin (2021); Vanhamäki *et al*. (2019)	24

ID	Factor	Supporting literature	Number of mentions from interviews (n=32)
O-5	value recovery	Alexandri *et al*. (2020); Coppola *et al*. (2021); Donner *et al*. (2020); Egelyng *et al*. (2018); Hagman and Feiz (2021); Lange *et al*. (2021); Lesage-Meessen *et al*. (2018); Nagarajan *et al*. (2020); Salvador *et al*. (2021c); Sherwood (2020); Stegmann *et al*. (2020)	23
O-6	valorisation of bioresources	Barros *et al*. (2020); Berbel and Posadillo (2018); Cheng *et al*. (2020); Coppola *et al*. (2021); Donner and de Vries (2021); Donner et al. (2020); Egelyng et al. (2018); Jarre *et al*. (2020); Konwar *et al*. (2018); Mohan *et al*. (2016); Mpofu *et al*. (2021); Nagarajan *et al*. (2020); Odegard *et al*. (2012); Overturf *et al*. (2020); Santagata *et al*. (2021); Shirsatha and Henchion (2021); Trømborg *et al*. (2013); Ubando *et al*. (2020); Zecevic *et al*. (2019)	24
O-7	exploring the local economy	Barcelos *et al*. (2021); Barros *et al*. (2020); De Laporte *et al*. (2016); Donner and de Vries (2021); Mengal *et al*. (2018); Paredes-Sánches *et al*. (2019); Salvador *et al*. (2021c); Santagata *et al*. (2021); Taffuri *et al*. (2021); Tsai and Lin (2021)	7
O-8	developing new markets	Campuzano and González-Martínez (2016); DeBoer *et al*. (2020); Gyalai-Korpos *et al*. (2018); Näyhä (2020); Salvador *et al*. (2021c); WBCSD (2019)	0

Source: Author (2021)

O-3: lower production costs when using bioresources/biowaste. Using bioresources/waste can (but not necessarily and always will) lower costs for, for instance, the production of enzymes, bioplastics, and other products of high value. These bioproducts can be produced from by-products from other processes or systems. Moreover, the raw materials might be obtained on less costly operations since they might be produced rather than only extracted or exploited.

O-4: waste recovery. Biowaste, such as food waste, municipal solid waste (MSW) (or the organic fraction of it), animal manure, and other wastes of many systems, can be turned into value-added products. Those can be used to produce (e.g.) biofuels, organic fertilisers, and a range of other products. Nonetheless, the range of existing products can widen upon innovation.

O-5: value recovery. Rather than directly targeting bioenergy, by-products or biowaste can be converted into higher value-added products. The value of these resources can be enlarged by promoting a hierarchy of application pathways to benefit from them, hence targeting the options with the highest values. For instance, wrong-shaped carrots and outer leaves of lettuce, given adequate pre-processing and logistics, can be used in pre-made food instead of ending up in animal feed.

O-6: valorisation of bioresources. Valorisation of biomass can take place through raw material co-streams and waste. Biomass use reaches its maximum value when used for pharmaceutical purposes (e.g., medicine and fine chemicals for purposes of health and lifestyle), only then food and animal feed, followed by chemicals, biofuel, compost, and lastly energy (electricity and heat), as per the biomass value pyramid of Verburg (2007). One of the options to seek valorisation of bioresources is via upcycling. Nonetheless, apart from pursuing pharmaceutical uses, seeking to drive potential by-products into products of human consumption is not automatically the best economic option, since quality requirements for certain labels of pet food might be more rigid than for human food in general.

O-7: exploring the local economy. Bio-based industries seek to locally produce food and feed, on top of materials, chemicals, and fuels from domestic renewable resources. Exporting might not be attractive, greatly due to the costs of logistics and environmental impacts.

O-8: developing new markets. The possibility of new products might motivate the creation or development of new markets. Within that context, biorefineries can entail the production of several products, to various end markets.

Nevertheless, the transition to a CBE business can be given by motivating industry players to invest in such bio-based business while still maintaining their market position with an existing production, while new markets are developed. Developing new markets and reshaping existing ones is important for a CBE, since the development and evolution of the CBE, with new technologies and business approaches, will encourage the transition to bio-based products substituting non-renewable, fossil-based ones, where the need for customer awareness and education will be brought about.

4.2 REGIONAL ASPECTS OF CIRCULAR BIOECONOMY SYSTEMS

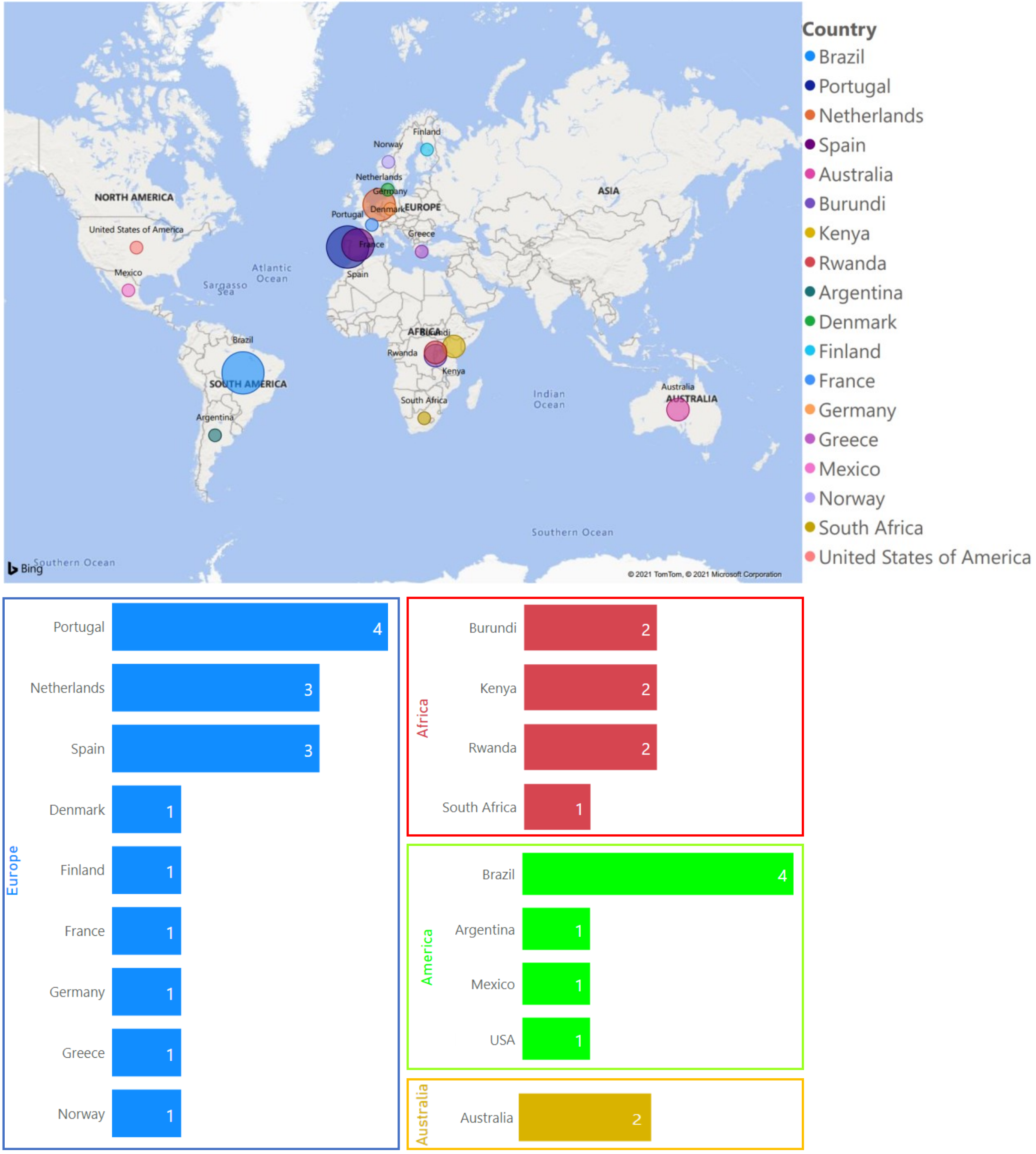
This section firstly depicts the demographics of the stakeholders interviewed and then presents the main results of the interviews with BE businesses, drawing on the regional differences about the motivations for adopting CE practises as well as a more specific perspective of barriers, challenges, drivers, and opportunities, across four continents.

4.2.1 Demographics

Organisations from 18 countries in four continents participated in the interviews. Half of the participating organisations were from Europe (see Figure 12, page 80), with exactly 50% of the total number of countries (9 out of 18) in which the organisations' practises take place. Africa and America had the same participation (approximately 22% each) with 4 countries each. Australia presented the smallest participation (approximately 6%).

Although invitations were sent to companies from Asian countries, no organisation from the region responded and participated in the practise review, thus no recommendations could be drawn for the continent.

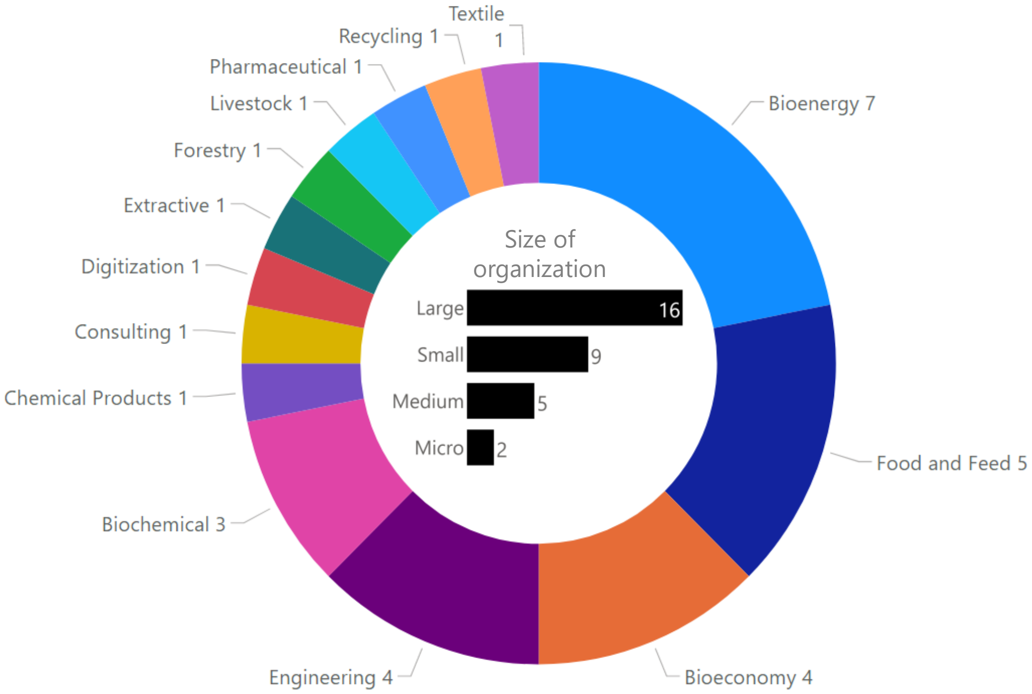
Figure 12 - Geographic location of participating organisations



Source: Author (2021)

In Graph 1 (page 81) one can see the 13 sectors in which the organisations participate. Bioenergy and Food and feed are the most representative, representing 37.5% of the participating organisations. Another 34.4% comprised organisations from the sectors labelled as Biochemical, Bioeconomy, and Engineering. The remaining 28.1% of organisations are from a variety of other sectors. Graph 1 also shows that half of the participating organisations were large (250+ employees), while 34% were small or micro, and 16% were medium.

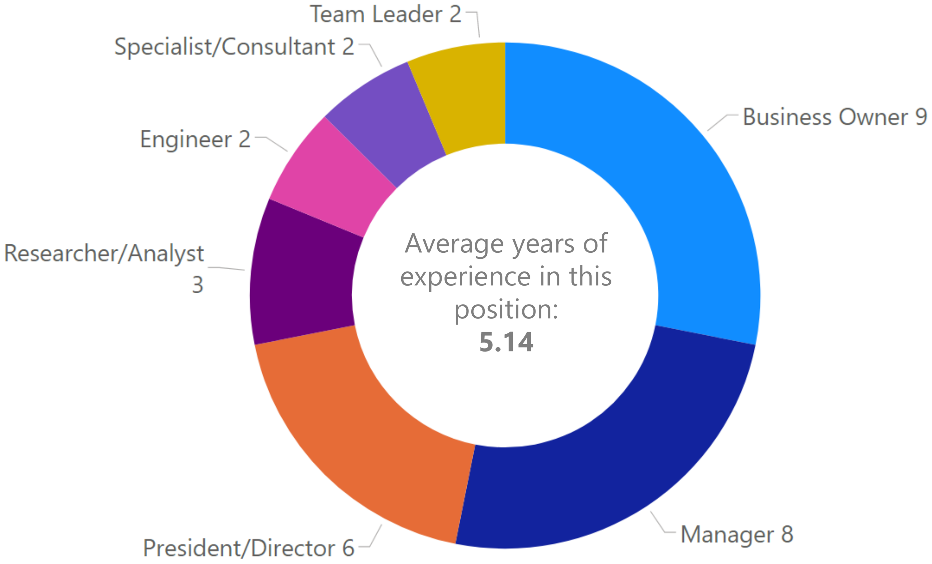
Graph 1 - Sector and size of participating organisations



Source: Author (2021)

Graph 2, in turn, shows that the participating representatives within each organisation occupy a variety of positions, and most participants have strategic roles within the respective organisation. Moreover, the average years of experience in the position occupied by the participants was five years and one month (5.14 years).

Graph 2 - Position in the organisation and average years of experience of interviewees



Source: Author (2021)

4.2.2 Main Reasons for Adopting Regional CBE Practises

In Africa, the motivation for establishing CBE practises seems to be rooted in social concerns coupled with environmental care, where minimisation of costs and optimisation of resource use ranks second. A range of reasons have been provided by interviewees, which include providing increased dignity, improving people's living standards by creating jobs and increasing wealth (and thus giving people a chance to put their children in school), growing quality food at an affordable price, and improving people's health by enabling them to eat organic food. Interviewees also mentioned protecting the environment and contributing to lowering GHG emissions, by (e.g.) recycling waste, creating competitive advantage by reducing costs, increasing monetary gains, and diminishing dependence on imports as key reasons.

The reasons for adopting CBE practises in American countries are rooted in cost reductions and monetary gains, and compliance with regulatory requirements coupled with environmental concerns. Specific reasons included: reducing costs and optimising the use of resources, compliance with environmental regulation, concerns towards increased environmental sustainability (e.g., less carbon-intensive production, and overall reduced environmental impacts).

In European countries, the main reasons for adopting CBE practises lie primarily on environmental care (mainly driven by the reduction of environmental impacts by replacing the use of fossil resources) followed by saving on costs and optimising the use of resources, gaining competitive advantage (having a competitive edge), and complying with regulation (e.g., extended producer responsibility).

In Australia, the motivation for CBE systems is based on greater sustainability, avoiding the waste of resources, mitigating climate change impacts, enabling access to bioenergy, and saving on costs.

4.2.3 Barriers and Challenges for Regional CBE Systems

As barriers and challenges sometimes overlap in a practical perspective, they are presented jointly in this section.

4.2.3.1Africa

The key barriers and challenges for CBE businesses in Africa are the following.

Technology. Access to affordable technology, and low level of readiness of technology available locally.

Government. Lack of governmental support or incentive through policies; slowness in administrative procedures for the implementation of the CBE practises and lack of a clear and coherent political framework to establish a more circular economy.

Costs. High investment costs, for initial investments or scaling-up; high costs of transportation, equipment, and maintaining staff; lack of financial incentives/policies.

New markets. Being a pioneer (or being too early for a market that is not ready) is usually a hurdle, as there are no customers in a non-existing market; there are also difficulties for newcomers to settle in a new environment, and there is lack of awareness from the consumer/market.

Collaboration. Building a sustainable (and constant) supply chain; relying on big partners and their infrastructure increases vulnerability by diminishing independence of business decisions, and scepticism or reluctance to engage in collaboration to share a technology, thus preventing to raise awareness.

Workforce. Lack of workforce willing to do manual jobs such as sorting waste.

Culture. People see non-traditional products and practises as tabu; lack of awareness makes people sceptical of the benefits of new practises.

COVID-19-related challenges. Effects of the COVID-19 pandemic have forced companies to put operations on hold for undetermined periods of time.

4.2.3.2America

The main difficulties for CBE businesses in America are depicted hereafter.

Lack of awareness. Lack of awareness or knowledge of what a CBE is; cultural challenges need to be overcome for shifting to new products, services, or businesses altogether; consumers are not completely aware of the sustainability benefits of recovering value from by-products and might be sceptical of the use of side streams as feedstocks (they might not want to buy or have low expectations - which can lower willingness to try - over something they know was made from a by-product).

Costs. High initial costs for implementing new practises or technologies.

Regulation and policy support. Lack of regulation and policy support favouring products resulting from more circular or cleaner supply chains; existing regulations that require investments in new technologies and other capital investments.

Collaboration. Need to overcome the fear of collaboration and sharing information and responsibilities.

Capabilities and infrastructure. Lack of general infrastructure for consumers to shift to new products or services (e.g., replacing diesel engines with biomethane engines - difficulty in finding a repair shop or fuel stations); need for capacity building (e.g., training personnel on technical skills).

Bureaucracy. Bureaucracy (mainly internal) can prevent companies from going forward with projects or delaying the development of new products.

Stakeholder risk adversity. Shareholders do not want to be the first to try a new technology or are sceptical about the new practises being profitable.

New markets. Need for developing new markets and raising awareness through research, development, and innovation, and making it public.

Logistics. Logistic challenges for commercialising bio-based (e.g.) food products include limited time for handling and consuming before expiration.

4.2.3.3Australia

The difficulties for CBE businesses in the case of Australia are presented hereafter.

Regulation. In Australia, each state has a different regulation on environmental protection, making it difficult for businesses to work in different states; overregulation might be in place for products/streams that do not carry a high risk.

Policy stability. Having clear, well-flagged, and stable policies.

Access to capital incentives. CBE businesses can be capital-intensive, and even though there have been incentives (e.g., Biofutures Program) they might not be of easy access.

Technology-cost competitiveness. Technologies that promote a more circular BE might not be commercially competitive with other practises yet.

Stakeholder risks adversity. Stakeholders do not want to be the first to try a new technology.

4.2.3.4Europe

Drawing on the overall barriers and challenges, the difficulties for BE businesses in Europe to chart a more circular path include a few specifics.

Technology. Low level of technology-readiness (i.e., uncertainty of functional performance, reliability on technology - thus how long it will last) in some sectors, and high costs of developing new and making use of recently developed technology (especially for newcomers).

Openness to innovation. Some industries are still very traditional, with a linear mindset (need for a shift of the mentality of the industry).

Lack of knowledge and awareness (internal). Lack of business acumen (especially for newcomers, competing with well-established businesses), and lack of technical knowledge on ever-developing technology and for finding useful end-uses for side streams.

Lack of awareness (external). Lack of awareness both from the consumer and the producer side (market/supply chain).

Feedstock. Finding feedstock that do not compete with food production, at a feasible price, and with the right level of availability/scale.

Regulation. Lack of regulatory stability (changes in government and therefore regulatory requirements), and regulatory impediments (when it is necessary to have a licence to trade side streams, even for companies that might be part of the same group).

Collaboration. Lack of collaboration for solving a problem (company individualism), and difficulty in finding the correct partners, getting them onboard and working together.

Costs and price competitiveness. Higher costs (including infrastructure and operations) compared to traditional (linear and/or synthetic) alternatives, and low-price competitiveness with fossil-based alternatives.

Scaling-up. Buyers (B2B and B2C) might not be willing to try out new products; need for supplier development (a network of suppliers will not exist - at least on a large scale - until the technology and the product are well-established).

COVID-19-related challenges. Need for restructuring supply chains (e.g., extraction/collection and transportation of resources) due to economic fallout.

4.2.4 Drivers and Opportunities for Regional CBE Systems

As drivers and opportunities also sometimes overlap in a practical perspective, they are presented jointly in this section.

4.2.4.1 Africa

The main existing aspects that enable a CBE in Africa include the following.

Community support. Good support from local communities and partners.

Environmental protection. Promoting agroecological farming and a conservative agriculture; promoting circular systems by recovering value from waste and (e.g.) making organic products.

Positive social impact. Contributing to eradicating malnutrition by providing cheaper food alternatives, which is good for the population and good for the business; creating jobs; promoting cleanliness and hygiene; contributing to a sustainable development of the country.

Cleaner production. Organic products (e.g.) are known to have a premium price, which motivates farmers/producers.

Other aspects mentioned as enablers of a CBE in Africa in the future include:

- Raising awareness among the population to make them understand the good foundations of a CE;
- The renewal of the economy, allowing GDP growth based on a balance between demand, production, and fair income.

4.2.4.2America

The overall drivers and opportunities for businesses in a CBE in America include the following.

Public policies. Public policies promoting more circular practises (although not using the term CE nor BE), bringing benefits such as financial incentives and tax exemption.

Regulation. Regulation of products with more environmentally responsible practises, such as by demanding reverse logistics.

Reducing costs. Reducing costs with increased circularity by (e.g.) internalising flows of resources (mainly from the recovery of waste).

Competitive advantage. Having a competitive edge because of more environmentally friendly products, which can place a company ahead of competitors and future regulations.

Lower environmental impacts. Reducing GHG emissions, compared to traditional product offers (e.g., renewable energy from waste).

Increasing awareness. Consumer awareness is increasing, and the market has been requiring cleaner practises from manufacturers; supply chain partners as well as consumers also have been requiring greater transparency, which leads to an accelerated shift.

Facilitated financing options. Financial institutions open to discuss and support business opportunities linked to renewable alternatives.

Other drivers and opportunities for a CBE in America to be explored in the future are:

- Need for increased awareness and education on what a BE and a CBE are, and their benefits, as well as the need for a more sustainable future;
- Need for collaboration (establishing multidisciplinary teams) and symbiosis;
- Need for governmental support in Latin America, by establishing public policies and governmental subsidies that incentivise the adoption of CBE practises (financial incentives, tax exemptions, etc., to reduce initial costs).
- Acknowledging the positive externalities (e.g., contribution to SDGs) derived from renewable and circular alternatives in contrast to non-renewable and circular ones (in monetary terms).

4.2.4.3Australia

The main aspects that act as enablers of a CBE in Australia are presented hereafter.

Acceleration programs. Acceleration programs for start-ups, which provide access to mentors and investors.

Policy drivers. Incentives for reducing carbon emissions and climate change impacts, as well as for producing renewable energy.

Circular procurement. Asking suppliers about recovered content.

Other aspects that were mentioned as enablers of a CBE in Australia in the future (that are not in place at the moment) include:

- Collaboration for solving a problem (e.g., tackling a particular waste);
- Information on material flows (thus tracking materials and finding management and circularity opportunities);
- Finding new markets for novel products (sometimes it might be possible to have a perfectly ready product from a reclaimed stream, but it necessary to find a market to buy it).

4.2.4.4Europe

The existing aspects that facilitate charting a more circular path for BE businesses in Europe include a few specifics.

Regulation. Bans (e.g., for plastic bags) and incentives implemented by regulations (e.g., biofuels) accelerate the uptake of product offers based on renewable sources; regulation for environmental protection.

Public policies. Public policies and financial incentives, through government subsidies, incentivising R&D for a CE and BE have been making an important contribution to the establishment and development of CBE businesses.

Internal and external awareness. Although it still might be a challenge in some sectors, in others public awareness and acceptance have been increasing, due to education and sensitisation of consumers, which can be seen by the demand for sustainable products; market awareness has also been increasing in some sectors, which can be seen by the search for sustainable and circular materials.

Alleviating environmental impacts. Replacing the use of fossil resources; reducing GHG emissions; eliminating disposable waste (thus closing cycles) and avoiding the use of toxic chemicals.

Competitive advantage. Access to new markets can lead to being ahead of competitors (first-mover advantage) and bring a positive image to the business.

Lowering costs. Wastes (in some sectors) can have lower costs than virgin materials, which can lead to cost-savings, as can optimising processes by narrowing the flows of resources.

Collaboration. Lack of collaboration can be a hurdle, but existing collaborations for R&D can be a driver for the uptake of more circular practises; networking and serendipity (by meeting the right people at the right time in the right place) can also bring opportunities.

Other aspects that were mentioned as enablers of a CBE in Europe in the future (that are not in place at the moment) include:

- Standardisation for environmental assessment of circular products;
- Higher taxes on fossil-based resources and lower prices and taxes on waste streams;
- Higher availability of raw materials/bioresources.

4.3 GENERAL DISCUSSIONS ON THE ASPECTS OF CBE SYSTEMS

The content of sections 4.1 and 4.2 helped achieve specific objective i. The greater number of participating organisations based in Europe shows the greater openness of European companies and the belief on both a BE and a CE. That is likely to be greatly influenced by the role played by the European Union, in incentivising and subsidising BE and CE initiatives.

On the other side of the spectrum, there is a perceived difficulty for American companies to dialogue and discuss their practises openly. It is still unknown the reasons why companies, especially in America but in other continents too, are not as willing to partake in CBE initiatives or share their knowledge and perception on the positive and negative aspects encountered in their paths, which could contribute to designing auto sufficient and resilient BMCBEs. Overall, there is a need for greater awareness about what a BE, a CE, and a CBE are among organisations in America.

Based on the results achieved, from a practise-based perspective, the barriers, and challenges most frequently addressed by the stakeholders interviewed should be prioritised when formulating public policies and when designing and adapting BMs, for they represent the most common hardships for CBE systems to emerge and develop. The same can be said of drivers and opportunities, as they represent the factors that more commonly boost CBE systems.

Overall, the key barrier (see Table 9) as pointed out by stakeholders was lack of financial resources/capital (B-4) (n=14), which was mentioned many times jointly with low technology-readiness level. On the opposite side, the least concerning barrier was the seasonality of feedstock (B-8) (n=2). Regarding challenges, the main challenge (see Table 10) has been price competitiveness (C-12) (n=14), which once again was mentioned many times together with lack of adequate technology, which needs to be both technically and economically feasible. The least concerning challenges were maintaining a uniform product (C-2) (n=0), motivating production of low-priced products (C-3) (n=0), final product quality/efficiency (C-13) (n=0), and lack of standardisation of inputs (C-19) (n=0).

When it comes to drivers, the main aspect perceived as a driver (see Table 11) by the participating organisations was establishment of public policies/governmental support (D-11) (n=18), which many times help to overcome barriers and lessen the burdens of challenges. The least contributing driver was waste management regulation (D-13) (n=2). The most prominent opportunities (see Table 12) were waste recovery (O-4) (n=24) and valorisation of bioresources (O-6) (n=24), which go alongside value recovery (O-5) (n=23). On the contrary, developing new markets (O-8) (n=0) was not seen as an opportunity for developing businesses in a CBE.

Therefore, advancing CBE systems would require, primarily, setting strategies to overcome the lack of financial resources/capital, by means of (for instance) financing options and incentives offered by either public or private organisations with the intent of offsetting the initial hardships of new business practises. Another highlight would be the need to develop and/or make adequate technology available locally, meaning that the technology needs to be economically accessible and the necessary chain of supply to maintain such technology in operation in the long term needs to be developed jointly. Moreover, price competitiveness with traditional (linear and non-renewable-based options) needs enabling.

To make it happen, along with developing the adequate technology, it is recommended that the incentives long given to fossil-based products be switched to renewable-based ones, and that taxes on non-renewable alternatives be raised and benefits be ceased. Moreover, establishing public policies and strategies for governmental support that enable value recovery (especially from waste) and valorisation of bioresources can more easily foment CBE systems.

On the more specific aspect of this research, identifying regional aspects of CBEs enables tailoring initiatives to accelerate the adoption of circular practises and the transition to an economy that is more circular and based on renewable resources. Therefore, it can help in building and advancing regional CBE systems.

There might be trade-offs both among barriers and challenges as well as among drivers and opportunities, such as for scaling up (C-1) and logistics management (B-1), for instance. While operations are small and pick-up/delivery points are close, logistics are less of an issue, scaling up might make logistics management more complex. Another issue linked to scaling-up is flexibility. Smaller many times means more flexible, which entails that businesses have more freedom to make decisions and take action, whereas scaling-up means to be less flexible. The complexity of transportation/logistics costs and management (B-1) can also be tied to lack of demand-pull effect (B-6). On the one hand, the greater the demand, the more complex it might be to manage; however, on the other hand, greater demand also might reduce the production costs by economies of scale.

Lack of financial resources/capital (B-4) and (partial) lack of governmental support (B-9) might be opposites too. At times, there are subsidies and fiscal/financial incentives that are exclusive or primarily for businesses with limited capital. Therefore, businesses with significant capital might not be eligible to benefit from certain aids.

Technological advancement (D-6) and bioenergy production (O-2) might also not go together. On the one hand, if bioenergy production yields immediate good monetary value for a business (without considering taking other valorisation routes) it can prevent technological development from happening or even slow it down, since it might deviate interests from developing technologies that allow maintaining resources in use for longer before being leaked back out to the environment. It can also affect the valorisation of bioresources (O-6). On the other hand, if there is technological advancement, and the manufacture of non-energy-related bioproducts gets prioritised, the production of bioenergy might be affected, and other sources used instead.

Making products with potentially lower environmental impacts (D-15) might affect the ability of businesses to lower production costs when using bioresources/biowaste (O-3), as well as value recovery (O-5) and might refrain them from exploring the local economy (O-7). Systems with the lowest costs might not yield the least environmental impacts, and the resources available locally might also not be able to provide the least impacts or the lowest costs. Moreover, alleviating resource supply risks (D-1) might lead to rebound effects, which might include the perception that reducing material leakage (D-2), as well as seeking a more efficient resource use (D-3) and designing out waste (D-4) are no longer needed.

There is also the possibility of dual action. Some of the factors presented and discussed here can have more than one effect on businesses, that is, some barriers can be both barriers and challenges at the same time (and this logic applies to challenges too), as well as some drivers can be both drivers and opportunities at the same time (and this logic applies to opportunities too).

A few barriers can, on top of preventing businesses to start circular practises, also withhold and/or slow down the development of the business, thus becoming challenges for BE businesses. Transportation/logistics costs and management (B-1), and lack of financial resources/capital (B-4), for instance, can force companies to innovate and "go around" them in order to put their businesses on the map. Overregulation or inadequate regulation (B-5) can also be wearying for companies to influence and change. Cultural unfitness (B-7) can be a challenge to be taken onboard in case a company decides to change their linear *status quo*. Finally, seasonality of feedstock (B-8), instead of preventing BE businesses from engaging in circular practises can be a challenging source of differentiation.

Moreover, some challenges can grow to become barriers too. The need of investments to integrate biorefineries (C-4) might be true for small businesses in the search for scaling-up (C-1), and if such investments do not take place, those businesses might reach a roadblock. In addition, depending on the market, lack of public/consumer awareness (C-7) can also become a barrier, since bio-based products will not attract consumers, leading to consumer avoidance towards products of non-primary cycles (C-9). Moreover, price competitiveness (C-12) (with non-renewable choices) and lack of adequate technology (C-16), depending on the depth of it, might impede businesses from continuing their activities altogether.

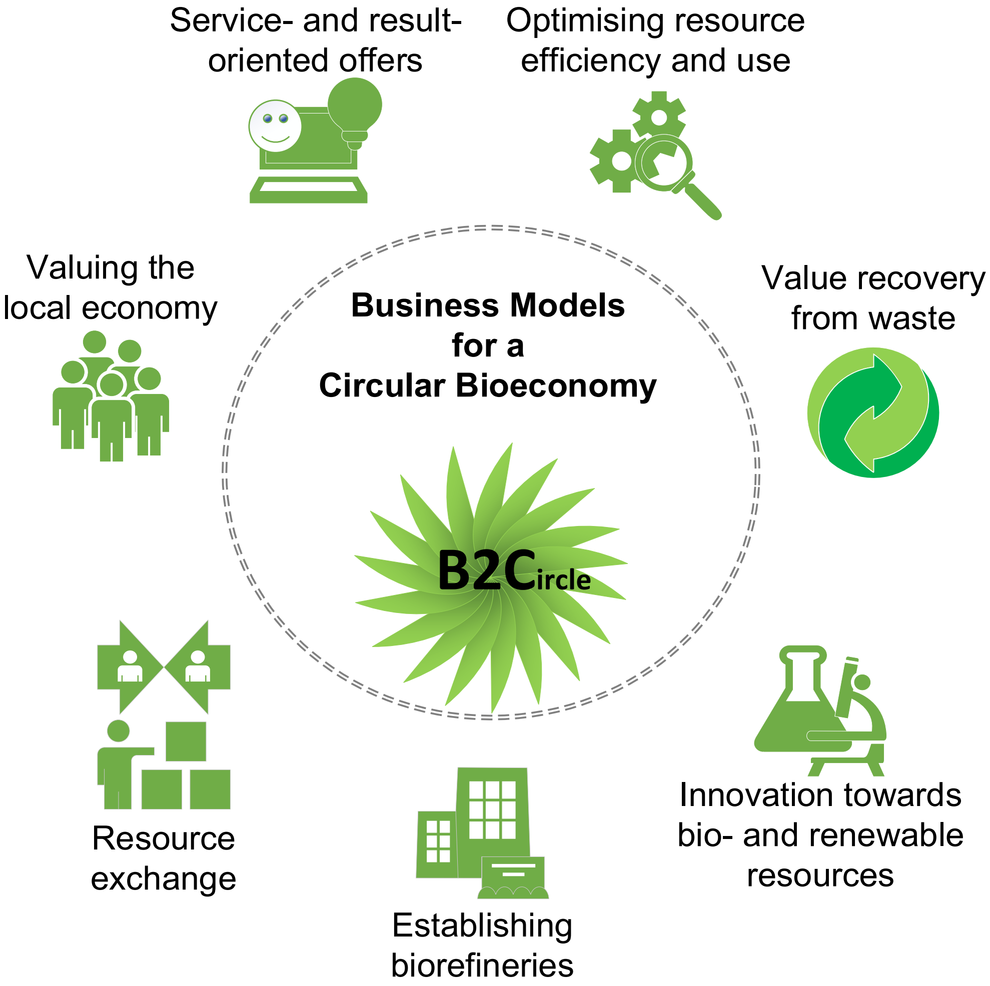
With regards to drivers who could also work as opportunities, one can cite more efficient resource use (D-3) and designing out waste (D-4), which might be noted or might take place only after the implementation of circular practises. Establishment of collaborations and networks (D-9) and establishment of public policies/governmental support (D-11) could also ease the path of a BE business into more circular practises by providing many forms of support to it, ranging from financial help/subsidies to offering advice and introducing to new markets. Moreover, the possibility of making products with potentially lower environmental impacts (D-15) might bring competitive advantage (D-7) to BE businesses, by acting as catalysts in spreading a good brand image and reputation. Furthermore, innovation (D-8), besides a driver for a CBE, can also assist seizing opportunities. It can be business- or technology-related. While technological innovation might bring about novel ways of recovering value of resources or making activities easier and/or cheaper, business innovation might be achieved via novel revenue streams, stakeholder relationships, or new markets.

Turning waste into bioproducts (O-1) and bioenergy production (O-2) can be driven by waste recovery (O-4) and value recovery (O-5), which can be strategies to lower production costs when using bioresources/biowaste (O-3). Therefore, businesses might engage in the manufacturing of bioproducts to design out waste and take advantage of it instead of simply disposing of it and losing its still embedded value, thus promoting the valorisation of bioresources (O-6). Nonetheless, it could also be driven by the desire for exploring the local economy (O-7) and taking advantage of locally available resources. Moreover, developing new markets (O-8), besides being seen as an opportunity by certain businesses who already produce or generate products or by-products in a BE business, others might be motivated to enter these new markets altogether once they start to note the benefits they can offer.

4.4 A TAXONOMY FOR BUSINESS MODELS FOR A CIRCULAR BIOECONOMY

This section presents the seven BMCBEs identified in Phase I (covering specific objective ii), which will be the basis of the self-assessment tool, named B2Circle, proposed in this dissertation. The seven BMCBEs are illustrated in Figure 13 (page 94).

Figure 13 - Business models for a circular bioeconomy



Source: Author (2021)

The seven BMCBEs are introduced in the following sections by bringing a description of the BM along with the strategies that can be deployed from them, the value proposition, creation and delivery, and capture, the SDGs (and specific targets) they contributes to, the supporting literature used as basis for their proposal, and the organisations (from the practise review) fitting their description, besides an example in practise, from one of the organisations in the practise review.

4.4.1 Optimising Resource Efficiency and Use

This BM (see details in Table 13, page 95) helps narrow and slow resource flows. It aims to use as little of a resource as possible relative to a certain product output and reduce or eliminate the generation of waste.

"*Optimising resource efficiency and use*" allows reducing the inputs of either primary or non-primary resources per unit of final product both at the production/manufacturing phase and at the use phase. Strategies to put this BM into practise include from making a product as lean as possible during its production (e.g., lean manufacturing) to making products fulfil their intended use to the greatest and most comprehensive extent (e.g., making a product last as much as possible at the use phase – high-quality and long-lasting products, such as quality wood panels that last longer –, or enable sharing to avoid waste – sharing food to prevent food waste).

Table 13 - Business model: optimising resource efficiency and use

Business Model	Optimising resource efficiency and use
Example strategies	Reduce or eliminate waste; Design out waste; Lean manufacturing; Offering refilling; Cascaded systems; Offering upgrade options; Offering durable and modular products; Offering repair and maintenance options.
Value proposition	Using less of a resource (material or energy) per unit of value offer, maximising efficiency and minimising resource consumption and costs.
Value creation and delivery	Activities and resources for reaching maximum efficiency during production (e.g., reducing all forms of wastes), and partners for achieving extended value during the use phase, as well as for distribution. Targeting or developing adequate customer segments to receive the value offer, and designing strong relationships with customers.
Value capture	Cost reductions are enabled by preventing waste generation and consequently increasing efficiency. Durable products can benefit from premium pricing and the offer of services of (e.g.) repair and maintenance. Modular products enable marginal revenue in case of upgrades. Environmental value is captured by avoiding wastes to be generated (material or energy) and disposed of.
SDGs it contributes to	2 - Zero Hunger (2.4) 6 - Clean Water and Sanitation (6.4; 6.A) 8 - Decent Work and Economic Growth (8.4) 9 - Industry, Innovation and Infrastructure (9.4) 11 - Sustainable Cities and Communities (11.6) 12 - Responsible Consumption and Production (12.2; 12.3; 12.4; 12.5) 13 - Climate Action (13.3; 13.B) 14 - Life Below Water (14.1) 15 - Life on Land (15.4)
Reference/Example	Bocken *et al*. (2014); D'Amato *et al*. (2020); Donner *et al*. (2020); EMF (2016); EMF (2017a); EMF (2017b); EMF (2019); EMF (2021b); EMF (2021c); Näyhä (2019); Näyhä (2021); Petit-Boix and Leipold (2018); Rodias *et al*. (2021); Salvador *et al*. (2021c); WBCSD (2019)
Practise (Organisation Number)	12, 14, 22, 24

Source: Author (2021)

4.4.1.1 Example in practise

Organisation 12: Total utilisation of seaweed. Harvesting seaweed and extracting the total value available in the seaweed as efficiently as possible comprise the main activities at Organisation 12, related to this BM.

"*[We] harvest seaweed, extract lots of different materials. What other companies are doing is they extract one component and basically throw the rest away. The next company extracts another component and throws the rest away […]. Because we have this step-by-step process, we also use much less energy than other companies, because you have to consider things like you harvest the seaweed and if you have this same material you once bring it into solution and all these washing steps and so on, and you save enormous amounts of water and energy by cascaded extraction*". Organisation 12 operates in a B2B context and reports that being efficient and more environmentally friendly than many competitors gives them a competitive edge before their customers.

4.4.2 Value Recovery from Waste

This BM (see details in Table 14, page 97) helps close and narrow resource flows. It aims to recover the value of resources that have already gone through one or more processing cycles and are considered by-products or wastes by engaging them in a new life cycle.

"*Value recovery from waste*" allows reducing the need for (virgin) raw material and the amount of waste sent to landfills or having final destinations with lower added value. At the same time, it contributes to reducing environmental impacts (e.g., climate change) (CORCORAN; HUNT, 2021). Strategies to put this BM into practise include from the use of Take-back systems (TBS) to recover products at their end-of-life to, then, give appropriate final destination (e.g., collecting worn-out wood products such as furniture), to making energy recovery from livestock (e.g., producing biogas from cattle or pig manure, and upgrading it into biomethane to be used as car fuel, or use biogas for heating, and using the digestate as biofertilizer).

Table 14 - Business model: value recovery from waste

Business Model	Value recovery from waste
Example strategies	Algae for wastewater treatment; Producing bioenergy from organic waste (biogas via anaerobic digestion); Composting; Upcycling; Take-back systems (TBS); Second and third generation biofuels; Reconditioning; Remanufacturing; Refurbishing; Reusing; Recycling; Repurposing waste streams towards greater added-value routes.
Value proposition	Value offers from bio-waste streams, taking advantage of wastes that would have been disposed of or needed treatment, benefiting the producer and user of the value offer and the waste generator.
Value creation and delivery	Activities, resources, and partnerships to enable investment, operations, and maintenance of facilities and technology to trade and process waste streams (e.g., receiving, sorting - if/when necessary -, storing, and extracting the most value from those resources through different technological routes). Managing customer segments, as well as setting adequate relationships and channels for receiving or sending out waste streams (e.g., transportation and storage) for distribution and commercialisation.
Value capture	Costs can be reduced by using wastes as inputs (own waste or from others). Waste recovery and making products from waste can be commercialised as a waste treatment service. Environmental externalities (from recovering waste) can enable premium pricing of final products. Environmental value is captured by avoiding disposal of waste (e.g., landfilling) and substituting virgin resources with waste.
SDGs it contributes to	2 - Zero Hunger (2.4) 6 - Clean Water and Sanitation (6.3) 7 - Affordable and Clean Energy (7.2) 8 - Decent Work and Economic Growth (8.4) 9 - Industry, Innovation and Infrastructure (9.4) 11 - Sustainable Cities and Communities (11.6) 12 - Responsible Consumption and Production (12.2; 12.3; 12.4; 12.5) 13 - Climate Action (13.3; 13.B) 14 - Life Below Water (14.1) 15 - Life on Land (15.4)
Reference/Example	Bocken *et al*. (2014); Brunnhofer *et al*. (2020); Carraresi and Broring (2021); Corcoran and Hunt (2021); Donner and Radic (2021); Donner and Vries (2021); Donner *et al*. (2020); Donner *et al*. (2021); EMF (2015); EMF (2017a); EMF (2017b); EMF (2019); EMF (2020a); EMF (2020b); EMF (2021b); EMF (2021c); Mohan *et al*. (2018); Näyhä (2019); Paes *et al*. (2019); Petit-Boix and Leipold (2018); Rodias *et al*. (2021); Ryabchenko *et al*. (2017); Salvador *et al*. (2021c); WBCSD (2019)
Practise (Organisation Number)	1, 2, 4, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31

Source: Author (2021)

4.4.2.1Example in practise

Organisation 21: Making biofertilizer from faecal matter. Collecting faecal matter from installed latrines and processing it into biofertilizers comprise the main activities at Organisation 21, related to this BM. "*It utilises fully decomposed (human) faecal matter, as well as a urine-dilution to be used as organic fertiliser, for both the domestic and agricultural market.*

The fully decomposed faecal matter is collected from these pit-latrines every 3-6 months. Human faeces are not rejected. They are collected to be used in agriculture as human fertiliser manure (this manure is used in our coffee plantations as well as in banana plantations, beans, cassava, artmisia, onions, etc.) […]. The manure and urine-dilution are organic fertilisers, that are sold to the […] farmers to grow and treat their […] trees […]. No chemical fertilisers are used, as it has shown to spoil the quality of the soil significantly, affecting the quality [of the plants] […]. This manure makes it possible to obtain a large production both for our food crops and for industrial crops. Once there is production, there is consumption. Through the metabolism within the human body there is production of urine and faeces, so the cycle begins again". Organisation 21 operates in a B2B approach and has reported that their BM also brings economic and social benefits to the local community, since the biofertilizer is less costly than chemical fertiliser, which they need to import), and provides a more environment-friendly production, since the input of chemicals is reduced (less chemical fertiliser).

4.4.3 Innovation Towards Bio- and Renewable Resources

This BM (see details in Table 15, page 99) helps close, narrow, and slow resource flows. It aims to encourage making products from bio-based and renewable resources, especially in substitution of non-renewable and non-biobased ones.

"*Innovation towards bio- and renewable resources*" allows shifting to a bio-based economy by promoting products that are made from renewable bioresources. It seeks to contribute to reducing environmental impacts by avoiding the use of fossil resources and fomenting products that take into consideration their end-of-life at the development stage. Strategies to put this BM into practise include repurposing resource streams towards greater added-value routes (e.g., using wastewater to recover valuable resources such as phosphorus and nitrogen, rather than using it as a substrate for further processing and energy recovery) or producing first generation biofuels (e.g., using dedicated sugarcane crops to produce 1st generation bioethanol).

Table 15 - Business model: innovation towards bio- and renewable resources

Business Model	Innovation towards bio- and renewable resources
Example strategies	Research & development & innovation; Producing bioplastics; First generation biofuels; Making biomass pellets from harmful agal blooms; Circular procurement; Repurposing resource streams towards greater added-value routes; Biomimicry-inspired innovation; Replacing non-renewable resources.
Value proposition	Making novel value offers using renewable sources, replacing value offers made from non-renewable sources, thus lowering environmental impacts.
Value creation and delivery	Activities, resources, and partners to enable efficient research & development & innovation towards the use of bio-based and renewable resources in innovative value offers. Creating, managing, or developing customer segments, and creating strong customer relationships to accept the value offer. Building partnerships through adequate channels for distribution and commercialisation.
Value capture	Premium pricing can be adopted for using bio-based and renewable resources, especially in substitution of traditional non-renewable options. Environmental value is captured by preventing the use of fossil resources and their related emissions (during extraction, use, and disposal).
SDGs it contributes to	2 - Zero Hunger (2.4) 6 - Clean Water and Sanitation (6.3) 7 - Affordable and Clean Energy (7.2; 7.A) 9 - Industry, Innovation and Infrastructure (9.4; 9.5) 11 - Sustainable Cities and Communities (11.6) 12 - Responsible Consumption and Production (12.2; 12.3; 12.4; 12.5; 12.7) 13 - Climate Action (13.3; 13.B) 14 - Life Below Water (14.1) 15 - Life on Land (15.4)
Reference/Example	Corcoran and Hunt (2021); D'Amato *et al*. (2020); EMF (2015); EMF (2016); EMF (2017a); EMF (2017b); EMF (2019); EMF (2020a); EMF (2020b); EMF (2021b); EMF (2021c); Gatto and Re (2021); Mohan *et al*. (2018); Petit-Boix and Leipold (2018); Rodias *et al*. (2021); WBCSD (2019)
Practise (Organisation Number)	4, 7, 10, 11, 13, 14, 17, 25, 26, 28, 30, 31, 32

Source: Author (2021)

4.4.3.1Example in practise

Organisation 10: Producing recyclable and biodegradable biopolymers. Doing research & development & innovation activities, including chemical and physical analyses, and LCAs for developing recyclable and biodegradable biopolymers comprise the main activities at Organisation 10 at the moment, related to this BM. "*These biopolymers are not easily mechanically recyclable as PET or HDPE. Their recycling is chemical recycling […]. Basically, these biopolymers are expected to go to four specific areas, home cleaning, automotive, adhesives (coatings), structural adhesives formulation additives […]. What we want to do is to recover these products at the end of their lives through chemical recycling and convert them again into the same elements […].*

For specific cases where the biopolymer cannot be recovered at the end-of-life the aim is for biodegradation". Organisation 10 is aiming to produce two streams of biopolymers, for different uses: chemically recyclable biopolymer which can be taken back at the end-of-life and recycled into the same polymer, and a biodegradable polymer, for uses when it is not possible to recover it at the end-of-life. The target customer will depend on the end application. These biopolymers will bring the advantage of substituting currently existing polymers made from non-renewable resources, and, especially for the chemically recyclable one, it will allow a full circle, where the product as a whole can be once again converted into the same product.

4.4.4 Establishing Biorefineries

This BM (see details in Table 16, page 101) helps close and narrow resource flows. It aims to establish facilities that can be shared between companies or product systems to make bioproducts in order to take advantage of using similar or the same resource streams or using similar or the same infrastructure.

"*Establishing biorefineries*" allows taking advantage of opportunities for helping close flows of resources, without having to move those for long distances to reach their respective processing facilities or taking advantage of shared facilities and resources. Thus, the core concept around this BM is sharing. In a biorefinery, a company or group of companies can share either feedstock or facilities. In this BM, companies can reduce investment and operational costs by using shared existing infrastructures (GYALAI-KORPO *et al.*, 2018). Strategies to put this BM into practise include using the same feedstock or using the same facilities. By (e.g.) using the same feedstock, it is possible to produce a number of interconnected products in a cascaded way, where the inputs for each product are based on different stages of the processing of the original feedstock (e.g., a biorefinery can be established for the production of ethanol from sugarcane, and subsequently use vinasse – waste from distillery – to produce biogas to power the facilities or use it as fertiliser in sugarcane fields). By using the same facilities, in an integrated production, resources from different origins can also be used to make the same or different products and share not only manufacturing but also administrative resources, structure, and facilities.

Table 16 - Business model: establishing biorefineries

Business Model	Establishing biorefineries
Example strategies	Sharing facilities; Sharing resources; Forming clusters or networks of companies; Forming cooperatives and bioproduction parks; Vertical or horizontal integration of production.
Value proposition	Bioproducts based on material and/or energy offers, produced in non-dedicated or shared facilities, targeted to the same or different customer groups.
Value creation and delivery	Activities and resources for managing shared facilities and resources (natural, technical, and energy). Partnerships for collaboration in operations, maintenance, and distribution channels, coordinating receipt and delivery of resources and products. Engaging in shared activities with partner companies when customer segments are the same or closely related.
Value capture	Costs are reduced by sharing facilities (either between companies or between product systems), as well as avoided transportation of supplies or final products to customers. Environmental value is captured by avoiding the use of excess resources due to shared operations.
SDGs it contributes to	2 - Zero Hunger (2.4) 6 - Clean Water and Sanitation (6.3) 7 - Affordable and Clean Energy (7.2) 8 - Decent Work and Economic Growth (8.4) 9 - Industry, Innovation and Infrastructure (9.4) 12 - Responsible Consumption and Production (12.2; 12.3; 12.4; 12.5) 13 - Climate Action (13.3; 13.B) 14 - Life Below Water (14.1) 15 - Life on Land (15.3; 15.4)
Reference/Example	Brunnhofer *et al.* (2020); Donner and Vries (2021); Donner *et al.* (2020); EMF (2015); EMF (2017a); EMF (2017b); EMF (2021b); Gyalai-Korpo *et al.* (2018); Mohan *et al.* (2018); Negi *et al.* (2021)
Practise (Organisation Number)	10, 12, 18, 24, 26

Source: Author (2021)

4.4.4.1Example in practise

Organisation 14: Producing compostable packaging from bioresources and using own waste to power processing mobile facilities. Using dedicated crops to regenerate land and produce compostable bio-based packaging comprise the main activities at Organisation 14, related to this BM. "*What we're dealing with is waste valorisation and land revalorisation. So, we are looking for waste from wine, agrowaste from wine residues, but it can be residues from different kinds of agricultural residues […]. On the land revalorisation is basically marginal land […] where we plant a specific dedicated feedstock that overtime improves the composition of the soil, but at the same time we harvest this plant which requires no irrigation, no pesticides, no fertiliser, nothing. And what we do then is we mix this dedicated feedstock with the agrowaste, and what we produce is 100% home sustainable packaging, compostable […].*

[At the same time, we] use the waste through anaerobic digestion to create energy, which will then power our other systems that are producing the packaging". Organisation 14 is still on a piloting phase and has not scaled-up operations. They use mobile units (thus the biorefinery facilities) to operate on the field to process their feedstock. Thus, they can take advantage of reduced transportation of feedstock to processing facilities, and at the same time can benefit from operating close to their targeted customer base, as they can have different mobile units at different locations to produce and supply locally, reducing costs and environmental impacts.

4.4.5 Resource (Raw Material and Waste) Exchange

This BM (see details in Table 17, page 103) helps close and narrow resource flows. It aims to establish connections between companies or product systems (e.g., business units within the same company) to enable exchanges of resources (either primary or wastes) for processing into value-added products.

"*Resource (raw material and waste) exchange*" allows closing loops by connecting outputs from a system to the inputs of another system, and narrowing flows of resources by decreasing the need for extracting raw materials from nature, as they are already in the Technosphere, thus saving energy, for instance, and contributing to reduce related environmental impacts. This BM might be especially successful in regions where there are companies processing different types of biomasses (GYALAI-KORPO *et al.*, 2018). Strategies to put this BM into practise include repurposing resource streams towards greater added-value routes (e.g., using wastewater to recover valuable resources such as phosphorus and nitrogen, rather than using it as a substrate for further processing and energy recovery) or producing second generation biofuels from agricultural waste (e.g., using crop waste from agriculture to produce 2nd generation biodiesel).

Table 17 - Business model: resource (raw material and waste) exchange

Business Model	Resource (raw material and waste) exchange
Example strategies	Industrial symbiosis; Buying or receiving resource flows from others; Selling or giving away resource flows to others.
Value proposition	Bridging different production systems to close loops by exchanging either primary resources, by-products, or waste streams, avoiding spending unnecessary material and energy to extract and/or process virgin materials.
Value creation and delivery	Activities, resources (e.g., especially logistics-related), and partners (supplier or receiver of the exchanged flow) for pick-up and delivery of resource streams. Setting adequate channels for exchanging resources (e.g., logistics and storage).
Value capture	Costs can be reduced using waste streams rather than virgin resources, and the overprocessing of resources. Dedicated businesses can profit from establishing connections/matches between different companies who have resources to exchange. Environmental value is captured by the avoided overprocessing of resources and the use of waste streams instead of virgin resources (when it be the case).
SDGs it contributes to	7 - Affordable and Clean Energy (7.2) 8 - Decent Work and Economic Growth (8.4) 9 - Industry, Innovation and Infrastructure (9.4) 11 - Sustainable Cities and Communities (11.6) 12 - Responsible Consumption and Production (12.2; 12.3; 12.4; 12.5) 13 - Climate Action (13.3; 13.B) 14 - Life Below Water (14.1) 15 - Life on Land (15.4)
Reference/Example	Donner *et al.* (2020); Donner *et al.* (2021); EMF (2017a); EMF (2017b); EMF (2020a); EMF (2021b); Gyalai-Korpo *et al.* (2018); Näyhä (2019); Petit-Boix and Leipold (2018); WBCSD (2019)
Practise (Organisation Number)	9, 15, 21, 22

Source: Author (2021)

4.4.5.1Example in practise

Organisation 9: Producing paper from recovered fibres (reclaimed paper) and exchanging waste streams between business units and with other companies. Collecting and receiving reclaimed resources, exchanging side streams within different business units and with other companies, comprise the main activities at Organisation 9, related to this BM. "*We use a lot of recycled fibre in our production […]. Basically, the paper is collected and then we have the deinking process in the several of our mills. The deinking process sort of purifies the wastepaper and take the inks out and makes the new pulp out of it, which is called recycled fibre, and then that is used as raw material for paper manufacturing […]. Some years ago, I think [the content of recycled fibre] is roughly 30%, now it might have decreased a little bit. [The reclaimed paper] is normally sold, the households are already sorting it […]. It depends on the location.*

In some places the households are sorting, for instance, cardboard and paper together, and then after that, those are separated in our separate sorting plants and the paper is brought to our mill. [In some places] the households are already sorting the paper separately, then it is just collected at the household. […] One of our biggest businesses is biorefining. There we have, like, several pulp mills, and then in the chemical pulp production, one of the residues that is generated in the process is crude tall oil […] and we use the crude tall oil there as raw material to produce renewable diesel, as a fuel for cars for instance, and we also produce renewable naphtha out of that. This naphtha can be used as a dropping chemical to produce, for instance, fossil-free plastic […]. We also have several biomass boilers in our different production units, and those normally recover the energy from our own organic, mainly organic, side streams. So, they are basically incinerated there to produce energy, but then of course, they are not 100% organic, so the inorganic part remains as ash, and this ash we have several utilisations for that as well. Some of them are internal but actually quite a lot is also ending up being external end-use, so, for instance, our ash is used for soil stabilisation, and in different kinds of earth construction projects. Then it is also used as raw material in cement industry". Organisation 9 has reported to have specific targets to be met in the coming decade, on the use of resources and the generation of disposable waste, adopting a responsible role towards extended producer responsibility. Currently, they exchange most of the waste they generate among the different business units and with other companies when the use of the side stream falls out of their expertise and level of technological readiness.

4.4.6 Valuing the Local Economy

This BM (see details in Table 18, page 105) helps close and narrow resource flows. It aims to prioritise meeting the needs and reaping benefits from the local economy towards the production and commercialisation of bio-based products.

"*Valuing the local economy*" allows benefiting from the local resources, community, and businesses to establish resilient and low-impact systems. Focusing on the inner loops, businesses that adopt this BM seek to act as locally as possible, generating benefits to the immediately close society making use of locally available resources, and identifying local demands to propose innovative product offers.

Strategies to put this BM into practise include prioritising local suppliers (e.g., acquiring raw materials from suppliers located within 20km rather than suppliers located 100km away), and offering products needed by local customers (e.g., building insect farms to supply cheap and locally produced protein). This BM helps develop the local economy by building strategic partnerships to enable local businesses to remain competitive. It helps lower environmental impacts by avoiding excessive motion/transport and helps reduce waste of biodegradable resources by them not having to be kept in storage for too long before transportation.

Table 18 - Business model: valuing the local economy

Business Model	Valuing the local economy
Example strategies	Prioritising local suppliers and local customers; Valuing the local economy.
Value proposition	Prioritising inner loops, and building business resilience by benefiting from partnering with local suppliers and meeting the needs of local customers
Value creation and delivery	Activities and partnerships to prioritise the local economy (e.g., suppliers and customers) using locally available resources. Creating or developing, and managing local customer segments. Building strong relationships with customers, as well as with suppliers. Designing adequate distribution channels for local commercialisation.
Value capture	Costs (especially logistic costs) can be reduced by switching to local suppliers and markets. Special deals can result from partnerships with local business partners. Environmental value is captured by avoided unnecessary transportation (through long distances) of both supplies (virgin or secondary material) and final products.
SDGs it contributes to	2 - Zero Hunger (2.4; 2.C) 8 - Decent Work and Economic Growth (8.4) 9 - Industry, Innovation and Infrastructure (9.3; 9.4) 11 - Sustainable Cities and Communities (11.C) 12 - Responsible Consumption and Production (12.2; 12.3; 12.4; 12.5) 13 - Climate Action (13.3; 13.B) 15 - Life on Land (15.3; 15.4; 15.9)
Reference/Example	EMF (2015); EMF (2017a); EMF (2019); EMF (2020b); EMF (2021b); Salvador *et al.* (2021c); WBCSD (2019)
Practise (Organisation Number)	1, 3, 16, 18, 20, 21, 22

Source: Author (2021)

4.4.6.1Example in practise

Organisation 16: Producing maggots for fish feed based on household waste. Collecting organic waste and rearing maggots comprise the main activities at Organisation 16, related to this BM. "*After graduation, from my master's […] I experienced how they feed maggots for the fish and then I see how that's very efficient, and everyone can afford to do it […].*

As aquaculture consultant I go around the country looking how the people they are feeding their fish farms. So, most of them are facing the challenge of, like, the fish feed. All of them keep saying the fish feed is very expensive, very expensive, so, then the idea comes to my mind, when I was in my class, we do feed [maggots] for the tilapia or catfish […] I started a business with my small land, I started to build some structure […]. We collect all the household waste […], we transport it […] we mill, that domestic waste, we mill it, we crush it, in the substance, we digest it […]. I select four to ten guys in the city and tell them I need this, I need this, I need this, I need this. After collecting maybe around one ton or two tons, I come with the pick-up and I pick it and then we go there on the site. They already sorted and collected the things I need. I train them to collect the things I need to feed my business […]. Normally, if you want to do as a business-oriented, you have to sell the dry [maggot] one and the fresh one. The dry one is for the factory, who will make the substitute to replace the fish meal […]. We replace fish meal to use insect meal, that was my thought when I started this business […]. They can feed [the maggots] directly to the fish". Organisation 16 grows maggots to be used as fish meal, which is sold fresh and is said to be much cheaper than traditional (dry) fish food. Besides, to make the business happen, they use local workforce, hiring personnel to collect wastes from households, and they prevent organic waste from going to landfills.

4.4.7 Service- and Result-oriented Offers

This BM (see details in Table 19, page 107) helps narrow and slow resource flows. It aims to provide service offers to customers instead of selling products and transferring the responsibility of product use and final destination to consumers.

"*Service- and result-oriented offers*" allows benefiting from closer relationships between producers and customers or consumers. It helps prevent wastes, for the producer is responsible for the material product that delivers the value offer, i.e., the customer does not own the product and is not held responsible for the management of its production and end-of-life. Nonetheless, legal contracts often define the terms of use.

Strategies to put this BM into practise include establishing product-service-systems (PSS) (e.g., offering to provide installed and maintained furniture made of wood-based panels for a certain period of time - 5 years).

Table 19 - Business model: service- and result-oriented offers

Business Model	Service- and result-oriented offers
Example strategies	Product-service systems (PSS); Extended producer responsibility; Service provision (waste treatment with upcycling purposes).
Value proposition	Engaging with closer relationships with customers by offering services and results instead of merely delivering material products.
Value creation and delivery	Activities and partners to deliver and manage service offers based on bio-based material or energy resources. Resources to run and manage contracts with specific customer segments, as well as develop strong relationships and gather feedback from customers. Develop adequate channels (own or through partners) for commercialisation (e.g., distribution and take-back).
Value capture	Revenue is based on service delivery and results, defined by contractual agreements. Environmental value is captured especially by product stewardship through extended producer responsibility (e.g., lower environmental impacts by avoided waste generation and obsolescence).
SDGs it contributes to	2 - Zero Hunger (2.C) 6 - Clean Water and Sanitation (7.2) 8 - Decent Work and Economic Growth (8.4) 9 - Industry, Innovation and Infrastructure (9.4) 12 - Responsible Consumption and Production (12.2; 12.3; 12.4; 12.5) 13 - Climate Action (13.3; 13.B) 14 - Life Below Water (14.1)
Reference/Example	EMF (2017b); Salvador *et al.* (2021c)
Practise (Organisation Number)	31

Source: Author (2021)

4.4.7.1Example in practise

Organisation 31: Food catering. Offering food products made from by-products of the brewer industry and supplying them for catering in events comprise the main activities at Organisation 31, related to this BM. "*We have a technology that is patent-pending that can be used to upcycle organic products […]. We started with brewery wastes, which are our partners, and developed a [spent grain] super flour. We use it to make a brownie mix, and we also do catering, selling brownies and taking them to the customer […]*". By offering the catering (service), Organisation 31 contributes to reducing food waste by managing the production of the food. It is also possible (but has not been reported by the company) to manage the end-of-life of leftovers properly, reducing overall impacts. That benefit can be added to the waste avoided in the production of the brownie, since it is already based on brewery by-products.

4.5 GENERAL DISCUSSIONS ON THE TAXONOMY OF BUSINESS MODELS FOR A CIRCULAR BIOECONOMY

The content in section 4.4 helped achieve specific objective ii. From the description of the BMCBEs presented in this section, one can see that all BMCBEs appear to help narrow the flows of resources, whereas closing loops is regarded as the second most concerning issue dealt with by the seven BMCBEs, followed by slowing resource flows. The strategies within the BMs will dictate how they will be tailored and what the highlighting traits of the BM will be. Moreover, the strategies listed in each BMCBE comprise only a set of examples of the strategies that could be deployed under the BM and are, by no means, exhaustive. Other strategies could be used to realise the BMs, and are, in fact, expected to be conceived through innovation to unlock the full potential of a CBE via effective BMs. Moreover, the strategies under each BM can vary, and the same strategy (or set of strategies) can fit in more than one BM, thus different BMs might overlap within the same organisation.

Regarding the SDGs, by individually analysing to which targets of which SDGs the BMCBEs contribute to, overall BMCBEs contribute mostly to achieving SDGs 9 (Industry, Innovation and Infrastructure), 12 (Responsible Consumption and Production) and 13 (Climate Action), with the seven BMCBEs contributing to them, followed by SDGs 2 (Zero Hunger), 8 (Decent Work and Economic Growth), 14 (Life Below Water), and 15 (Life on Land), with six BMCBEs contributing to them.

Moreover, the taxonomy for BMCBEs proposed in this dissertation was intended to encompass all possible BMs under a CBE perspective and be capable of capturing their nature on a general approach. One of the reasons for the descriptions of the BMs to be on a high level (thus not reaching a fine level of detail) is that they were intended to be holistic and be able to embrace a wide array of BMs with similar characteristics and intents, thus being “umbrella BMs”, that is why they have been referred to as overarching BMs during this research. Nonetheless, the researcher does not claim the list of BMCBEs to be exhaustive, for they were built under the experience obtained from the literature and practise reviews and further expertise could lead to a different arrangement for proposing the taxonomy and slightly different descriptions of the BMCBEs proposed. However, up to the date this dissertation was written, the taxonomy was believed to be representative of the existing BMCBEs and be able to describe the array of BMCBEs in practise.

5 RESULTS AND DISCUSSIONS FROM STRUCTURING THE TOOL - PHASE II

This section presents the results and discussions from the definition of criteria used to profile the BMCBEs and, afterwards, the different rounds of the Delphi approach aiding this study, which was used to structure the tool.

5.1 CRITERIA TO PROFILE AND TO SET APART THE OVERARCHING BUSINESS MODELS FOR A CIRCULAR BIOECONOMY

After the investigation described in section 3.2.1, the criteria defined for each building block and the alternatives within each criterion were defined and are shown in Table 20, along with the supporting literature.

Table 20 - Criteria and alternatives per business model building block

Building Block (BB)	Criterion	Alternatives	Supporting Literature
Users and Contexts	Nature of product offer	[Product; Service]	Brunnhofer *et al.* (2020); Carraresi and Broring (2021); Corcoran and Hunt (2021); D'Amato *et al.* (2020); Donner and Radic (2021); Donner and Vries (2021); Donner *et al.* (2021); EMF (2017b); EMF (2020b); EMF (2021b); EMF (2021c); Gyalai-Korpos *et al.* (2018); Petit-Boix and Leipold (2018); Salvador *et al.* (2021c); WBCSD (2019)
	Immediate customer	[Business-to-business (B2B); Business-to-consumer (B2C)]	Brunnhofer *et al.* (2020); Carraresi and Broring (2021); Donner and Vries (2021); Donner and Radic (2021); Donner *et al.* (2021); Donner *et al.* (2020); EMF (2021b); Gatto and Re (2021); Näyhä (2019); Näyhä (2021); Rodias *et al.* (2021); Salvador *et al.* (2021c)
Value proposition	Market strategy	[Low cost; Differentiation; Focus (market segmentation)]	Brunnhofer *et al.* (2020); Carraresi and Broring (2021); D'Amato *et al.* (2020); Donner and Radic (2021); Donner and Vries (2021); Donner *et al.* (2020); Donner *et al.* (2021); EMF (2020a); EMF (2020b); EMF (2021b); Gatto and Re (2021); Mohan *et al.* (2018); Näyhä (2021); Negi *et al.* (2021); Rodias *et al.* (2021); Salvador *et al.* (2021c); WBCSD (2019)
	Production scale	[Specialty products; Production in bulk]	Donner and Radic (2021); Donner *et al.* (2020); EMF (2015); EMF (2017a); EMF (2019); EMF (2020b); EMF (2021b); Gatto and Re (2021); Näyhä (2021); Salvador *et al.* (2021c); WBCSD (2019)

Building Block (BB)	Criterion	Alternatives	Supporting Literature
Revenues	Nature of revenue	[Product-based / short-term profitability; Service-based / long-term profitability]	Brunnhofer *et al.* (2020); Donner and Radic (2021); EMF (2020b); EMF (2021b); Näyhä (2019); WBCSD (2019)
	Impact of revenue	[Generating revenue for the company; Generating revenue for the company and for partners]	D'Amato *et al.* (2020); Donner and Vries (2021); EMF (2015); EMF (2017a); EMF (2021b); Salvador *et al.* (2021c)
Costs	Nature of costs	[Fixed costs; Variable costs]	Carraresi and Broring (2021); D'Amato *et al.* (2020); Donner et al. (2020); Donner *et al.* (2021); Näyhä (2021); Paes *et al.* (2019); Rodias *et al.* (2021); Salvador *et al.* (2021c)
	Origin of costs	[Investment costs; Operational costs]	Brunnhofer *et al.* (2020); Carraresi and Broring (2021); Corcoran and Hunt (2021); D'Amato *et al.* (2020); Donner and Radic (2021); Donner *et al.* (2020); Donner *et al.* (2021); Gyalai-Korpos et al. (2018); Negi *et al.* (2021); Paes *et al.* (2019); Rodias *et al.* (2021); Ryabchenko *et al.* (2017); Salvador *et al.* (2021c)
Mission	Mission driver	[Environment-driven; Economy-driven; Socially-driven; Innovation/technology-driven]	Carraresi and Broring (2021); D'Amato *et al.* (2020); Donner and Radic (2021); Donner and Vries (2021); Donner *et al.* (2020); Donner *et al.* (2021); EMF (2016); EMF (2017a); EMF (2019); EMF (2020a); EMF (2021b); EMF (2021c); Gatto and Re (2021); Gyalai-Korpos *et al.* (2018); Petit-Boix and Leipold (2018); Näyhä (2019); Näyhä (2021); Negi *et al.* (2021); Paes *et al.* (2019); Salvador *et al.* (2021c); WBCSD (2019)
Key activities	Type of activity	[Research & Development & Innovation; Marketing/Commercial; Operational; Management]	Brunnhofer *et al.* (2020); Corcoran and Hunt (2021); Donner and Radic (2021); EMF (2015); EMF (2016); EMF (2017a); EMF (2020b); Mohan *et al.* (2018); Näyhä (2021); Negi *et al.* (2021); Paes *et al.* (2019); Petit-Boix and Leipold (2018); Salvador *et al.* (2021c)
Partners	Type of partner	[Academia/University; Industry/Company; Government/Public organisation]	Brunnhofer *et al.* (2020); Corcoran and Hunt (2021); D'Amato *et al.* (2021); Donner and Radic (2021); Donner and Vries (2021); Donner *et al.* (2020); Donner *et al.* (2021); EMF (2017a); EMF (2019); EMF (2021b); Gyalai-Korpos *et al.* (2018); Mohan *et al.* (2018); Näyhä (2019); Näyhä (2021); Negi *et al.* (2021); Salvador *et al.* (2021c); WBCSD (2019)
	Position of partner in the value chain	[Upstream; Downstream]	Carraresi and Broring (2021); D'Amato *et al.* (2021); Donner and Radic (2021); Donner and Vries (2021); Donner *et al.* (2020); Donner *et al.* (2021); EMF (2017a); EMF (2019); EMF (2021b); Näyhä (2019); Salvador *et al.* (2021c); WBCSD (2019)

Building Block (BB)	Criterion	Alternatives	Supporting Literature
Natural resources	Origin of natural resources	[Primary-use natural resources; Non-primary-use natural resources]	Donner *et al.* (2020); EMF (2015); EMF (2016); EMF (2017a); EMF (2019); EMF (2020b); EMF (2021b); EMF (2021c); Näyhä (2019); Näyhä (2021); Petit-Boix and Leipold (2018); Rodias *et al.* (2021); WBCSD (2019)
Technical resources	Ownership of technical resources	[Own; Shared with partners; Outsourced]	Brunnhofer *et al.* (2020); D'Amato *et al.* (2020); Donner and Radic (2021); Donner and Vries (2021); Donner *et al.* (2020); Gyalai-Korpos *et al.* (2018); Salvador *et al.* (2021c)
Energy resources	Origin of energy resources	[Re-using resources to generate energy within the company; Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company]	Donner and Radic (2021); Donner and Vries (2021); Donner et al. (2021); EMF (2015); EMF (2017a); Gyalai-Korpos *et al.* (2018); Mohan *et al.* (2018); Näyhä (2019); Negi *et al.* (2021); Paes *et al.* (2019); Rodias *et al.* (2021); Ryabchenko *et al.* (2017); Salvador *et al.* (2021c); WBCSD (2019)
Next use	End-of-life management	[Upcycling; Downcycling; Sound disposal]	Corcoran and Hunt (2021); D'Amato *et al.* (2020); Donner and Radic (2021); Donner and Vries (2021); Donner *et al.* (2020); Donner *et al.* (2021); EMF (2015); EMF (2016); EMF (2017a); EMF (2019); EMF (2021b); EMF (2021c); Gatto and Re (2021); Gyalai-Korpos *et al.* (2018); Näyhä (2019); Salvador *et al.* (2021c); WBCSD (2019)
Distribution	Immediate customer	[Business-to-business (B2B); Business-to-consumer (B2C)]	Carraresi and Broring (2021); Donner and Vries (2021); EMF (2021b); Gatto and Re (2021); Rodias *et al.* (2021); Salvador *et al.* (2021c)
Positive Impacts	Dimension of positive impacts	[Environmental; Economic; Social]	Brunnhofer *et al.* (2020); Carraresi and Broring (2021); Corcoran and Hunt (2021); D'Amato *et al.* (2020); Donner and Radic (2021); Donner *et al.* (2021); Donner *et al.* (2020); EMF (2015); EMF (2016); EMF (2017a); EMF (2019); EMF (2020a); EMF (2020b); EMF (2021b); EMF (2021c); Gatto and Re (2021); Gyalai-Korpos *et al.* (2018); Petit-Boix and Leipold (2018); Mohan *et al.* (2018); Näyhä (2019); Negi *et al.* (2021); Paes *et al.* (2021); Rodias *et al.* (2021); Salvador *et al.* (2021c); WBCSD (2019)
Negative Impacts	Dimension of negative impacts	[Environmental; Economic; Social]	Corcoran and Hunt (2021); D'Amato *et al.* (2020); Donner and Radic (2021); Donner *et al.* (2021); Donner *et al.* (2020); EMF (2017a); Petit-Boix and Leipold (2018); Näyhä (2019); Negi *et al.* (2021); Paes *et al.* (2021); Rodias *et al.* (2021); Salvador *et al.* (2021c)

Source: Author (2021)

In total, 19 criteria were proposed, permeating the 14 building blocks of the Circular Canvas. They were conceived in a way that they should be able to profile and to set apart the different BMCBEs, thus pointing out the differences among them.

Furthermore, they were thought out to resemble the characteristics of a BM rather than the activities within a company, since even companies with the same BM can have different activities, work in different sectors, and make or commercialise different value offers.

Having defined the criteria based on the literature and practise reviews, they were sent to specialists to be assessed following a Delphi approach, as addressed in the next section.

5.2 FIRST ROUND - DELPHI

In the first round, 16 out of the 87 specialists (thus, 18% of the specialists contacted) participated to some extent. The distribution of the specialists who participated in the first round can be seen in Table 21.

Table 21 - Participating specialists - 1st round

Origin	From SLR (i)	From PR (ii)	From OR (iii)	Total
Academia	5	0	3	8
Industry	0	8	0	8

Source: Author (2021)

Hence, 50% of participating specialists were from academia and 50% from industry. Of those 16 specialists, seven were from Brazil, and the remaining were located one in each of the following countries: Australia, Finland, Germany, Italy, Kenya, Netherlands, Norway, Rwanda, and Spain. Table 22 shows how many specialists contributed to assessing the suitability of the proposed criteria, as well as the different BMCBEs.

Table 22 - Number of specialists who contributed to the different parts of the survey in the 1st round

Subject of assessment		Number of specialists who contributed to the assessment
Criteria	Assessing the suitability of criteria	16
Business Model for a Circular Bioeconomy	Optimising resource efficiency and use	11
	Establishing biorefineries	11
	Value recovery from waste	10
	Resource exchange	10
	Innovation towards bio- and renewable resources	10
	Valuing the local economy	10
	Service- and result-oriented offers	10

Source: Author (2021)

All 16 specialists contributed to assessing the suitability of the 19 criteria proposed. However, as pointed out to them in the survey, Part 3 (profiling BMCBEs) was not compulsory, and specialists could choose how many and which BMs they would want to assist profiling. At least 10 specialists helped profiling each of the seven BMCBEs.

5.2.1 Assessing the Suitability of the Proposed Criteria

When assessing the suitability of the criteria proposed to set apart the different BMCBEs, participants were asked whether each criterion should be kept in the assessment or excluded. All criteria were deemed suitable by the majority of respondents, as shown in Table 23.

Table 23 - Decision on criteria

Building Block	Criterion	Decision (Keep x Exclude)	Average agreement on decision
Users and Contexts	Nature of product offer	Keep criterion	94%
	Immediate customer	Keep criterion	100%
Value proposition	Market strategy	Keep criterion	94%
	Production scale	Keep criterion	100%
Revenues	Nature of revenue	Keep criterion	88%
	Impact of revenue	Keep criterion	88%
Costs	Nature of costs	Keep criterion	94%
	Origin of costs	Keep criterion	94%
Mission	Mission driver	Keep criterion	88%
Key activities	Type of activity	Keep criterion	94%
Partners	Type of partner	Keep criterion	88%
	Position of partner in the value chain	Keep criterion	81%
Natural resources	Origin of natural resources	Keep criterion	81%
Technical resources	Ownership of technical resources	Keep criterion	88%
Energy resources	Origin of energy resources	Keep criterion	81%
Next use	End-of-life management	Keep criterion	88%
Distribution	Immediate customer	Keep criterion	94%
Positive Impacts	Dimension of positive impacts	Keep criterion	94%
Negative Impacts	Dimension of negative impacts	Keep criterion	81%

Source: Author (2021)

Moreover, participants were asked whether new criteria could or should be proposed, within each building block (as per the Circular Canvas framework).

At the end of the 1st round, a few suggestions were registered. Each one was assessed to verify whether (a) it could be used to characterise a BM and not just define the characteristics of an organisation (even within the same BM), and whether (b) it was not captured by one of the existing criteria. The suggestions (per building block), and how they were dealt with, are presented in Table 24.

Table 24 - Suggestions for new criteria and alternatives

Building Block	**Suggestion**	**Added to assessment (Yes/No)**	**Reason for decision**
Users and Contexts	C2C (consumer to consumer); B2G (business to governement); B2E (business to employee); G2B (government to business); G2C (government to citizen); B2B2C (business to business to consumer); B2I (business to investor); D2C (direct to consumer).	No	It characterises the activities of a company, rather than the business model
Value proposition	How about certification? When we focus on the circular bioeconomy, recycling, and efficient resource use creat value for this direction. And certification does help to make materials and products more recognised and valued in the market.	No	It characterises the activities of a company, rather than the business model
Revenues	No suggestions	-	-
Costs	No suggestions	-	-
Mission	Sugestion: local-driven, region-driven, global-driven	No	It characterises the activities of a company, rather than the business model
	Recognition and acception by stakeholder groups is getting more attention nowadays. Perhaps only indicating general drivers would not very hepful, rather you should better make them more specific.	No	It did not contain a clear structure asked for in the survey: CRITERION (alternative 1, alternative 2, alternative n)
Key Activities	Type of activity (strategic planning, quality management, environmental management, process management)	No	They are already captured by "Management"
Partners	NGOs should be made clearly here. Also many stakeholders are not involved in the value chains but they have important roles to influence actors of the chains, e.g. NGOs or public consultancy.	No	It is already captured by "Industry/Company"
	Type of partner (investor, local community)	No	It characterises the activities of a company, rather than the business model

Building Block	Suggestion	Added to assessment (Yes/No)	Reason for decision
Natural Resources	Make the types of natural resources more specifically then your results should be more effective.	No	It did not contain a clear structure asked for in the survey: CRITERION (alternative 1, alternative 2, alternative n)
Technical Resources	Make the types of technical resources more specifically then your results should be more effective.	No	It did not contain a clear structure asked for in the survey: CRITERION (alternative 1, alternative 2, alternative n)
Building Block: Energy Resources	Renewable energy (power, heat, gas)	No	It characterises the activities of a company, rather than the business model
	Sugestion: renewable energy or not	No	It characterises the activities of a company, rather than the business model
	Make the types of energy more specifically then your results should be more effective.	No	It did not contain a clear structure asked for in the survey: CRITERION (alternative 1, alternative 2, alternative n)
Next Use	No suggestions	-	-
Distribution	Sugestion: kind of transport	No	It characterises the activities of a company, rather than the business model
	already use in another building block	Yes	This suggestion led the researcher to change the term "immediate customer" in building block "Users and contexts" to "final customer"
	Immediate customer (B2E (business to employee); B2B2C (business to business to consumer); D2C (direct to consumer))	No	It characterises the activities of a company, rather than the business model
Positive Impacts	positive impacts might include governance as well - which happens within the business dimensions.	No	These are captured by the three dimensions of sustainability, already added as alternatives to the criterion
	Dimension of positive impacts (innovation, technological)	No	These are captured by the three dimensions of sustainability, already added as alternatives to the criterion
Negative Impacts	similarly, negative impacts might also include governance as well - which happens within the business dimensions.	No	These are captured by the three dimensions of sustainability, already added as alternatives to the criterion
	Dimension of positive impacts (innovation, technological)	No	These are captured by the three dimensions of sustainability, already added as alternatives to the criterion

Source: Author (2021)

The remark made in the field to suggest criteria to the building block *Distribution* led the researcher to adjust the definition of a similar criterion in building block *Users and contexts*.

In both building blocks the criteria *immediate customer* with the same alternatives (*B2B* and *B2C*) existed. However, in *Users and contexts* the criterion was renamed to *final customer*, to better reflect the intent of collecting that information, as it should reflect whether the value offer is made to an individual (or group) or another organisation (or business); whereas in *Distribution*, it should reflect the immediate party receiving the value, i.e., if it is sold directly to the final consumer or commercialised with another business before reaching the final consumer. Moreover, at the end of the 1st round the BMCBEs were assessed according to the criteria proposed initially, as addressed in the next section.

5.2.2 Assessing the Overarching Business Models for a Circular Bioeconomy

The respondents assessed the seven BMCBEs according to the 19 criteria proposed initially. The ranking of the alternatives in each criterion, using FAHP as described in section 3.2.3.1, can be seen in Table 25 (page 117). The results of the assessments were analysed by the researcher, and a few incoherencies were spotted (highlighted in red in Table 25), which comprised the issues presented hereafter.

For *nature of product offer* (in building block *users and contexts*), in the BMCBE *Service- and result-oriented offers*, product resulted to be more representative than service.

For *immediate customer* (in building blocks *users and contexts* and *distribution*), the results were the same for both building blocks, even though in some BMCBEs products might be made for the consumer (users and contexts) but delivered to other businesses for sale (distribution). For that reason, the term has been changed to *final customer* in building block *users and contexts*.

For *origin of natural resources* (in building block *natural resources*), in the BMCBE *Value recovery from waste*, “primary-use natural resources” resulted to be more representative than “non-primary-use natural resources”.

These incoherencies were treated in the 2nd round of the Delphi sutudy by asking the specialists to reassess the alternatives within the criteria, as described in section 5.3. The CR described in section 3.2.3.3 was also calculated for every criterion, and the results are shown in Table 26 (page 120). All the assessments in the 1st round were consistent ($CR \leq 0.1$). Hence, no adjustments from judgements were necessary.

Table 25 - Assessment of the BMCBEs - 1st round

Building Block	**Criterion**	**Business Models for a Circular Bioeconomy**						
		Optimising resource efficiency and use	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Users and Contexts	Nature of product offer	Service	Product	Product	Product	Product	Product	Product
		Product	Service	Service	Service	Service	Service	Service
	Immediate customer	Business-to-consumer (B2C)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)
		Business-to-business (B2B)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)
Value proposition	Market strategy	Differentiation	Low cost	Low cost	Low cost	Differentiation	Low cost	Low cost
		Focus (market segmentation)	Differentiation	Differentiation	Differentiation	Focus (market segmentation)	Differentiation	Differentiation
		Low cost	Focus (market segmentation)	Focus (market segmentation)	Focus (market segmentation)	Low cost	Focus (market segmentation)	Focus (market segmentation)
	Production scale	Specialty products	Specialty products	Specialty products	Specialty products	Specialty products	Specialty products	Specialty products
		Production in bulk	Production in bulk	Production in bulk	Production in bulk	Production in bulk	Production in bulk	Production in bulk
Revenues	Nature of revenue	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Service-based / long-term profitability
		Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Product-based / short-term profitability
	Impact of revenue	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company	Generating revenue for the company	Generating revenue for the company	Generating revenue for the company	Generating revenue for the company
		Generating revenue for the company	Generating revenue for the company	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company and for partners
Costs	Nature of costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs
		Variable costs	Variable costs	Variable costs	Variable costs	Variable costs	Variable costs	Variable costs
	Origin of costs	Investment costs	Investment costs	Investment costs	Investment costs	Investment costs	Investment costs	Investment costs
		Operational costs	Operational costs	Operational costs	Operational costs	Operational costs	Operational costs	Operational costs

Building Block	**Criterion**	**Business Models for a Circular Bioeconomy**						
		Optimising resource efficiency and use	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Mission	Mission driver	Environment-driven	Environment-driven	Economy-driven	Environment-driven	Environment-driven	Environment-driven	Environment-driven
		Economy-driven	Economy-driven	Environment-driven	Economy-driven	Innovation/technology-driven	Socially-driven	Economy-driven
		Innovation/technology-driven	Socially-driven	Socially-driven	Socially-driven	Economy-driven	Innovation/technology-driven	Innovation/technology-driven
		Socially-driven	Innovation/technology-driven	Innovation/technology-driven	Innovation/technology-driven	Socially-driven	Economy-driven	Socially-driven
Key activities	Type of activity	Management	Research & Development & Innovation	Research & Development & Innovation	Research & Development & Innovation	Research & Development & Innovation	Management	Research & Development & Innovation
		Research & Development & Innovation	Operational	Operational	Management	Management	Operational	Management
		Operational	Management	Management	Operational	Marketing/Commercial	Research & Development & Innovation	Operational
		Marketing/ Commercial	Marketing/ Commercial	Marketing/ Commercial	Marketing/ Commercial	Operational	Marketing/ Commercial	Marketing/ Commercial
Partners	Type of partner	Industry/ Company	Academia/ University	Academia/ University	Academia/ University	Academia/ University	Academia/ University	Industry/ Company
		Academia/ University	Industry/ Company	Industry/ Company	Industry/ Company	Industry/ Company	Industry/ Company	Academia/ University
		Government/ Public organisation	Government/ Public organisation	Government/ Public organisation	Government/ Public organisation	Government/ Public organisation	Government/ Public organisation	Government/ Public organisation
	Position of partner in the value chain	Upstream	Upstream	Upstream	Upstream	Downstream	Upstream	Upstream
		Downstream	Downstream	Downstream	Downstream	Upstream	Downstream	Downstream
Natural resources	Origin of natural resources	Primary-use natural resources	Primary-use natural resources	Primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources	Primary-use natural resources
		Non-primary-use natural resources	Non-primary-use natural resources	Non-primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources	Non-primary-use natural resources

Building Block	Criterion	Business Models for a Circular Bioeconomy						
		Optimising resource efficiency and use	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Technical resources	Ownership of technical resources	Own	Own	Own	Own	Own	Own	Own
		Shared with partners	Shared with partners	Shared with partners	Shared with partners	Shared with partners	Shared with partners	Shared with partners
		Outsourced	Outsourced	Outsourced	Outsourced	Outsourced	Outsourced	Outsourced
Energy resources	Origin of energy resources	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company
		Acquiring energy (in the desired form) sources from outside the company	Acquiring energy (in the desired form) sources from outside the company	Acquiring energy (in the desired form) sources from outside the company	Acquiring energy (in the desired form) sources from outside the company	Acquiring energy (in the desired form) sources from outside the company	Acquiring energy (in the desired form) sources from outside the company	Acquiring energy (in the desired form) sources from outside the company
Next use	End-of-life management	Upcycling	Upcycling	Upcycling	Upcycling	Upcycling	Upcycling	Upcycling
		Downcycling	Downcycling	Downcycling	Downcycling	Downcycling	Downcycling	Downcycling
		Sound disposal	Sound disposal	Sound disposal	Sound disposal	Sound disposal	Sound disposal	Sound disposal
Distribution	Immediate customer	Business-to-consumer (B2C)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-consumer (B2C)
		Business-to-business (B2B)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-business (B2B)
Positive Impacts	Dimension of positive impacts	Environmental	Environmental	Environmental	Environmental	Environmental	Environmental	Environmental
		Economic	Economic	Economic	Economic	Social	Economic	Social
		Social	Social	Social	Social	Economic	Social	Economic
Negative Impacts	Dimension of negative impacts	Social	Economic	Social	Environmental	Social	Social	Environmental
		Environmental	Social	Economic	Social	Environmental	Environmental	Social
		Economic	Environmental	Environmental	Economic	Economic	Economic	Economic

Legend: ■ - 1st alternative most representative of the Business Model, 🟩 - 2nd alternative most representative of the Business Model, ▨ - 3rd alternative most representative of the Business Model, □ - 4th alternative most representative of the Business Model, 🟥 - incoherency detected

Source: Author (2021)

Table 26 - Consistency assessment for fuzzy analytic hierarchical process (FAHP) - 1st round

Building Block	Criterion	CR						
		Optimising resource efficiency and use	Establishing biorefineries	Value recovery from waste	Resource exchange	Innovation towards bio- and renewable resources	Valuing the local economy	Service- and result-oriented offers
Users and Contexts	Nature of product offer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Users and Contexts	Immediate customer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Value proposition	Market strategy	0.01	0.04	0.00	0.03	0.01	0.01	0.06
Value proposition	Production scale	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenues	Nature of revenue	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenues	Impact of revenue	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Costs	Nature of costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Costs	Origin of costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mission	Mission driver	0.06	0.01	0.03	0.03	0.02	0.02	0.01
Key activities	Type of activity	0.01	0.02	0.04	0.04	0.01	0.01	0.02
Partners	Type of partner	0.07	0.06	0.08	0.02	0.05	0.03	0.08
Partners	Position of partner in the value chain	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural resources	Origin of natural resources	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Technical resources	Ownership of technical resources	0.01	0.01	0.00	0.00	0.04	0.07	0.02
Energy resources	Origin of energy resources	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Next use	End-of-life management	0.00	0.01	0.00	0.00	0.01	0.01	0.00
Distribution	Immediate customer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Positive Impacts	Dimension of positive impacts	0.05	0.02	0.00	0.04	0.00	0.06	0.02
Negative Impacts	Dimension of negative impacts	0.00	0.00	0.00	0.00	0.00	0.00	0.01

Source: Author (2021)

5.3 SECOND ROUND - DELPHI

In the 2nd round of the Delphi approach, aiming to send the consolidated responses to the specialists and to treat the incoherencies found in the 1st round, another survey structured the same way as the one in the 1st round was sent to the same specialists (see Table 8, page 58), both the ones that participated in the 1st round and the ones who did not. In the 2nd round, 12 out of the 87 specialists (14% of the ones contacted) participated. The distribution of the specialists who participated in the 2nd round can be seen in Table 27.

Table 27 - Participating specialists - 2nd round

Origin	From SLR (i)	From PR (ii)	From OR (iii)	Total
Academia	4	0	3	7
Industry	0	5	0	5

Source: Author (2021)

Hence, 58% of participating specialists were from academia and 42% from industry. Of those 12 specialists, seven were from Brazil, and the remaining were located one in each of the following countries: Australia, Greece, Kenya, Netherlands, and Spain. Moreover, nine out of the 12 participants in the 2nd round had already participated in the 1st round, while three participants were new. In this 2nd round, the results presented in Table 25 were sent to the specialists in the form of a spreadsheet attached to the email, and they were asked to both review the results and report any further incoherencies at the end of the new survey. In the new survey they were asked to reassess the following criteria, once again for all seven BMCBEs:

- nature of offer (in building block *Users and contexts*) – previously named “nature of product offer”;
- final customer (in building block *Users and contexts*) – previously named “immediate customer”;
- immediate customer (in building block *distribution*);
- origin of natural resources (in building block *natural resources*).

The results obtained in the 2nd round replaced those of the assessment of the four criteria in the 1st round. The results obtained in the 2nd round can be seen in Table 28 (page 122), and the results of the CR for these new assessments can be seen in Table 29 (page 122).

Table 28 - Assessment of the BMCBEs - 2nd round

Building Block	Criterion	Business Models for a Circular Bioeconomy						
		Optimising resource efficiency and use	Establishing biorefineries	Value recovery from waste	Resource exchange	Innovation towards bio- and renewable resources	Valuing the local economy	Service- and result-oriented offers
Users and Contexts	Nature of offer	Product	Product	Product	Product	Product	Product	Service
		Service	Service	Service	Service	Service	Service	Product
	Final customer	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)
		Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)
Natural resources	Origin of natural resources	Primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources
		Non-primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources
Distribu tion	Immediate customer	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)
		Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)

Legend: ▨ - 1st alternative most representative of the Business Model, 🟩 - 2nd alternative most representative of the Business Model

Source: Author (2021)

Table 29 - Consistency assessment for fuzzy analytic hierarchical process (FAHP) - 2nd round

Building Block	Criterion	CR						
		Optimising resource efficiency and use	Establishing biorefineries	Value recovery from waste	Resource exchange	Innovation towards bio- and renewable resources	Valuing the local economy	Service- and result-oriented offers
Users and Contexts	Nature of offer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Users and Contexts	Final customer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural resources	Origin of natural resources	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Distribution	Immediate customer	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author (2021)

Moreover, the last question of the survey in this 2nd round asked respondents to indicate their agreement or disagreement with the consistency of the results shared with them (by email) by answering the following question: “Are the results consistent?”. They should provide one of the following answers: “Yes!”, in case they agreed with the results and no further incoherencies had been detected, or “No! Some criteria and alternatives (other than the ones being assessed in this 2nd round) need to be assessed further (please specify in the text box below)”, where they were asked to describe their concerns and explain the sources of incoherencies detected by them. All 12 participants answered “Yes!” to the question, thus requiring no further assessments. After that, the consolidated results were sent back to specialists in a 3rd round.

5.4 THIRD ROUND - DELPHI

In the 3rd round, the consolidated results, as shown in Table 30 (page 124) (final results from the 1st round deemed coherent, and the results of the 2nd round for the four criteria reassessed) were once again sent to all 87 specialists in the form of a spreadsheet, just as in the 2nd round, as all assessments from the 2nd round were found to be consistent. Table 31 (page 124) shows the consolidated CR for all criteria and BMCBEs, which were all deemed consistent ($CR \leq 0.1$).

In this 3rd round, specialists were asked to analyse the results within two weeks and were asked to write back to the researcher in case they judged that something was not correct or coherent. To date, no further incoherencies have been reported back to the researcher. Therefore, the final results, translated into the 9-point scale, which aided calculating the Euclidean distances for each criterion between the BM of the organisation using the tool and each of the seven BMCBEs, to be used in Phase III, are presented in Table 32 (page 128).

Table 31 consists of the deffuzified matrix containing the geometric mean of the assessments from all specialists, adjusted to the 9-point scale. Those make the profiles of the seven overarching BMCBEs identified in this research. This fulfils specific objective iv. Having finished the assessment of the seven overarching BMCBEs and having concluded Phase II of this research, the next Chapter presents the results of Phase III, which comprised testing the proposed self-assessment tool.

Table 30 - Consolidated assessment of the BMCBEs

Building Block	Criterion	Business Models for a Circular Bioeconomy						
		Optimising resource efficiency and use	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Users and Contexts	Nature of offer	Product	Product	Product	Product	Product	Product	Service
		Service	Service	Service	Service	Service	Service	Product
	Final customer	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)
		Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)
Value proposition	Market strategy	Differentiation	Low cost	Low cost	Low cost	Differentiation	Low cost	Low cost
		Low cost	Differentiation	Differentiation	Differentiation	Focus (market segmentation)	Differentiation	Differentiation
		Focus (market segmentation)	Focus (market segmentation)	Focus (market segmentation)	Focus (market segmentation)	Low cost	Focus (market segmentation)	Focus (market segmentation)
	Production scale	Specialty products	Specialty products	Specialty products	Specialty products	Specialty products	Specialty products	Specialty products
		Production in bulk	Production in bulk	Production in bulk	Production in bulk	Production in bulk	Production in bulk	Production in bulk
Revenues	Nature of revenue	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Product-based / short-term profitability	Service-based / long-term profitability
		Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Service-based / long-term profitability	Product-based / short-term profitability
	Impact of revenue	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company	Generating revenue for the company	Generating revenue for the company	Generating revenue for the company	Generating revenue for the company
		Generating revenue for the company	Generating revenue for the company	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company and for partners	Generating revenue for the company and for partners
Costs	Nature of costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs	Fixed costs
		Variable costs	Variable costs	Variable costs	Variable costs	Variable costs	Variable costs	Variable costs
	Origin of costs	Investment costs	Investment costs	Investment costs	Investment costs	Investment costs	Investment costs	Investment costs
		Operational costs	Operational costs	Operational costs	Operational costs	Operational costs	Operational costs	Operational costs

Building Block	Criterion	Business Models for a Circular Bioeconomy						
		Optimising resource efficiency and use	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Mission	Mission driver	Environment-driven	Environment-driven	Economy-driven	Environment-driven	Environment-driven	Environment-driven	Environment-driven
		Economy-driven	Economy-driven	Environment-driven	Economy-driven	Innovation/technology-driven	Socially-driven	Economy-driven
		Innovation/technology-driven	Socially-driven	Socially-driven	Socially-driven	Economy-driven	Innovation/technology-driven	Innovation/technology-driven
		Socially-driven	Innovation/technology-driven	Innovation/technology-driven	Innovation/technology-driven	Socially-driven	Economy-driven	Socially-driven
Key activities	Type of activity	Management	Research & Development & Innovation	Research & Development & Innovation	Research & Development & Innovation	Research & Development & Innovation	Management	Research & Development & Innovation
		Research & Development & Innovation	Operational	Operational	Management	Management	Operational	Management
		Operational	Management	Management	Operational	Marketing/Commercial	Research & Development & Innovation	Operational
		Marketing/Commercial	Marketing/Commercial	Marketing/Commercial	Marketing/Commercial	Operational	Marketing/Commercial	Marketing/Commercial
Partners	Type of partner	Industry/Company	Academia/University	Academia/University	Academia/University	Academia/University	Academia/University	Industry/Company
		Academia/University	Industry/Company	Industry/Company	Industry/Company	Industry/Company	Industry/Company	Academia/University
		Government/Public organisation	Government/Public organisation	Government/Public organisation	Government/Public organisation	Government/Public organisation	Government/Public organisation	Government/Public organisation
	Position of partner in the value chain	Upstream	Upstream	Upstream	Upstream	Downstream	Upstream	Upstream
		Downstream	Downstream	Downstream	Downstream	Upstream	Downstream	Downstream
Natural resources	Origin of natural resources	Primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources
		Non-primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources	Primary-use natural resources	Non-primary-use natural resources	Non-primary-use natural resources	Primary-use natural resources
Technical resources	Ownership of technical resources	Own	Own	Own	Own	Own	Own	Own
		Shared with partners	Shared with partners	Shared with partners	Shared with partners	Shared with partners	Shared with partners	Shared with partners
		Outsourced	Outsourced	Outsourced	Outsourced	Outsourced	Outsourced	Outsourced

Building Block	Criterion	Business Models for a Circular Bioeconomy						
		Optimising resource efficiency and use	Establishing biorefineries	Value recovery from waste	Resource exchange	Innovation towards bio- and renewable resources	Valuing the local economy	Service- and result-oriented offers
Energy resources	Origin of energy resources	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company	Re-using resources to generate energy within the company
		Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company	Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company	Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company	Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company	Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company	Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company	Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company
Next use	End-of-life management	Upcycling	Upcycling	Upcycling	Upcycling	Upcycling	Upcycling	Upcycling
		Downcycling	Downcycling	Downcycling	Downcycling	Downcycling	Downcycling	Downcycling
		Sound disposal	Sound disposal	Sound disposal	Sound disposal	Sound disposal	Sound disposal	Sound disposal
Distribution	Immediate customer	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)
		Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-consumer (B2C)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)	Business-to-business (B2B)
Positive Impacts	Dimension of positive impacts	Environmental	Environmental	Environmental	Environmental	Environmental	Environmental	Environmental
		Economic	Economic	Economic	Economic	Social	Economic	Social
		Social	Social	Social	Social	Economic	Social	Economic
Negative Impacts	Dimension of negative impacts	Environmental	Economic	Social	Environmental	Social	Social	Environmental
		Social	Social	Economic	Social	Environmental	Environmental	Social
		Economic	Environmental	Environmental	Economic	Economic	Economic	Economic

Legend: 🟩 - 1st alternative most representative of the Business Model, 🟩 - 2nd alternative most representative of the Business Model, 🟩 - 3rd alternative most representative of the Business Model, ⬜ - 4th alternative most representative of the Business Model

Source: Author (2021)

Table 31 - Consolidated consistency assessment for fuzzy analytic hierarchical process (FAHP)

		CR						
Building Block	**Criterion**	**Optimising resource efficiency and use**	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Users and Contexts	Nature of product offer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Users and Contexts	Immediate customer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Value proposition	Market strategy	0.01	0.04	0.00	0.03	0.01	0.01	0.06
Value proposition	Production scale	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenues	Nature of revenue	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Revenues	Impact of revenue	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Costs	Nature of costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Costs	Origin of costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mission	Mission driver	0.06	0.01	0.03	0.03	0.02	0.02	0.01
Key activities	Type of activity	0.01	0.02	0.04	0.04	0.01	0.01	0.02
Partners	Type of partner	0.07	0.06	0.08	0.02	0.05	0.03	0.08
Partners	Position of partner in the value chain	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural resources	Origin of natural resources	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Technical resources	Ownership of technical resources	0.01	0.01	0.00	0.00	0.04	0.07	0.02
Energy resources	Origin of energy resources	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Next use	End-of-life management	0.00	0.01	0.00	0.00	0.01	0.01	0.00
Distribution	Immediate customer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Positive Impacts	Dimension of positive impacts	0.05	0.02	0.00	0.04	0.00	0.06	0.02
Negative Impacts	Dimension of negative impacts	0.00	0.00	0.00	0.00	0.00	0.00	0.01

Source: Author (2021)

Table 32 - Consolidated assessment of BMCBEs in the 9-point scale

Building Block	**Criterion**	**Alternative**	**Business Models for a Circular Bioeconomy**						
			Optimising resource efficiency and use	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Users and Contexts	Nature of offer	Product	5.8823	6.2552	6.9090	5.9682	6.2269	6.0254	1.8459
		Service	3.1177	2.7448	2.0910	3.0318	2.7731	2.9746	7.1541
	Final customer	Business-to-business (B2B)	3.4593	4.4701	3.9231	4.4123	4.3079	3.9280	3.0825
		Business-to-consumer (B2C)	5.5407	4.5299	5.0769	4.5877	4.6921	5.0720	5.9175
Value proposition	Market strategy	Low cost	2.6621	4.3292	3.2419	4.1489	2.6557	3.9433	4.1168
		Differentiation	3.9348	2.6938	3.1832	2.6840	3.4213	2.9539	2.6242
		Focus (market segmentation)	2.4031	1.9770	2.5750	2.1671	2.9230	2.1028	2.2591
	Production scale	Specialty products	5.4644	5.7644	5.0695	5.3091	5.2481	6.0741	6.5687
		Production in bulk	3.5356	3.2356	3.9305	3.6909	3.7519	2.9259	2.4313
Revenues	Nature of revenue	Product-based / short-term profitability	5.4115	6.4424	6.5751	6.0941	5.6977	6.2784	3.9634
		Service-based / long-term profitability	3.5885	2.5576	2.4249	2.9059	3.3023	2.7216	5.0366
	Impact of revenue	Generating revenue for the company	3.9234	3.9779	4.8745	4.8324	5.4768	5.7247	5.1112
		Generating revenue for the company and for partners	5.0766	5.0221	4.1255	4.1676	3.5232	3.2753	3.8888
Costs	Nature of costs	Fixed costs	5.5084	5.8154	5.9380	5.3447	6.4639	6.1117	5.6977
		Variable costs	3.4916	3.1846	3.0620	3.6553	2.5361	2.8883	3.3023
	Origin of costs	Investment costs	6.4025	5.8278	4.8271	4.9410	6.3584	5.3882	5.7660
		Operational costs	2.5975	3.1722	4.1729	4.0590	2.6416	3.6118	3.2340

Building Block	Criterion	Alternative	Business Models for a Circular Bioeconomy						
			Optimising resource efficiency and use	Establishing biorefineries	Value recovery from waste	Resource exchange	Innovation towards bio- and renewable resources	Valuing the local economy	Service- and result-oriented offers
Mission	Mission driver	Environment-driven	2.6412	2.8616	2.5540	3.9372	2.8513	3.3220	3.8437
		Economy-driven	2.4710	2.3595	2.8968	1.7795	2.0962	1.6555	1.7820
		Socially-driven	1.8971	1.9020	1.8980	1.7136	1.9512	2.1269	1.6495
		Innovation/technology-driven	1.9908	1.8769	1.6511	1.5697	2.1013	1.8956	1.7248
Key activities	Type of activity	Research & Development & Innovation	2.3211	2.6792	3.2572	3.3914	3.3481	2.2204	2.8982
		Marketing/Commercial	1.8740	1.7908	1.6039	1.7602	1.9680	1.6031	1.7454
		Operational	2.1420	2.3397	2.1328	1.7672	1.6981	2.4120	2.0130
		Management	2.6629	2.1902	2.0060	2.0812	1.9857	2.7645	2.3435
Partners	Type of partner	Academia/University	3.1578	3.5826	3.7659	3.5763	3.7975	3.7403	3.3884
		Industry/Company	3.8332	3.1431	3.5083	3.3928	3.4302	3.1813	3.7244
		Government/Public organisation	2.0090	2.2743	1.7258	2.0309	1.7723	2.0784	1.8872
	Position of partner in the value chain	Upstream	5.2773	5.3462	5.6627	5.1164	4.1669	5.7149	4.7598
		Downstream	3.7227	3.6538	3.3373	3.8836	4.8331	3.2851	4.2402
Natural resources	Origin of natural resources	Primary-use natural resources	4.9465	4.6090	4.1078	4.2052	4.8062	4.5373	4.4118
		Non-primary-use natural resources	4.0535	4.3910	4.8922	4.7948	4.1938	4.4627	4.5882

Building Block	**Criterion**	**Alternative**	**Business Models for a Circular Bioeconomy**						
			Optimising resource efficiency and use	**Establishing biorefineries**	**Value recovery from waste**	**Resource exchange**	**Innovation towards bio- and renewable resources**	**Valuing the local economy**	**Service- and result-oriented offers**
Technical resources	Ownership of technical resources	Own	4.1854	4.6707	4.6069	3.6482	4.2494	3.6045	4.3127
		Shared with partners	2.5444	2.5633	2.3617	3.1296	2.5842	3.4965	2.6341
		Outsourced	2.2702	1.7660	2.0314	2.2222	2.1664	1.8990	2.0532
Energy resources	Origin of energy resources	Re-using resources to generate energy within the company	6.6241	5.6661	6.5755	5.3007	5.5773	5.4198	5.6497
		Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company	2.3759	3.3339	2.4245	3.6993	3.4227	3.5802	3.3503
Next use	End-of-life management	Upcycling	3.8607	4.2786	4.6274	4.5578	4.4288	5.0541	4.9479
		Downcycling	2.7123	2.8840	2.3266	2.6017	2.5423	2.2506	2.3521
		Sound disposal	2.4270	1.8374	2.0459	1.8405	2.0289	1.6953	1.7001
Distribution	Immediate customer	Business-to-business (B2B)	4.7670	5.6563	5.4142	4.1173	4.1788	3.6124	4.4712
		Business-to-consumer (B2C)	4.2330	3.3437	3.5858	4.8827	4.8212	5.3876	4.5288
Positive Impacts	Dimension of positive impacts	Environmental	4.4146	4.2977	4.1427	4.5567	4.3389	4.8140	4.6110
		Economic	2.7890	3.1328	2.7890	2.4608	2.2603	2.1143	1.8191
		Social	1.7965	1.5695	2.0683	1.9826	2.4008	2.0716	2.5700
Negative Impacts	Dimension of negative impacts	Environmental	3.2365	2.6606	2.7225	3.2222	2.9889	3.0309	3.3837
		Economic	2.6710	3.2595	2.9578	2.7347	2.8804	2.6323	2.6198
		Social	3.0924	3.0799	3.3197	3.0431	3.1307	3.3368	2.9966

Source: Author (2021)

5.5 GENERAL DISCUSSIONS ON THE STRUCTURING OF THE TOOL

The content in sections 5.1 and 5.2.1 helped achieve specific objective iii, and the content in sections 5.2 through 5.4 helped achieve specific objective iv.

The Euclidean distance is the most commonly method used for distance search (KHAIRI *et al.*, 2021). In the case of this research, it allows measuring the distance (in the 9-point scale) between the score of an alternative for an organisation using the tool's BM and that of the same alternative for each of the seven BMCBEs, therefore, showing how distant those parts of the BMs are from each other. The sum of all the Euclidean distances, for each alternative in each building block, when comparing the organisation using the tool's BM with each of the seven BMCBEs, will tell which of the BMCBEs is the most similar to the BM of the organisation using the tool. That means that the comparison that yields the smallest figure regarding the sum of the distances indicates the BMCBE that should be pursued by the organisation.

Although the BMCBEs presented in this dissertation are mutually exclusive, they can take place concomitantly in an organisation, i.e., the same organisation can be said to make use of more than one of the BMCBEs presented here. However, it is expected that one of them will be dominant over the other or others. Therefore, when suggesting a BMCBE using the self-assessment tool proposed in this dissertation, the profile built by the organisation using the tool might signal a profile that has similar characteristics to more than one of the BMCBEs, making the final score (SED) for two or more BMCBEs to be close. In case two or more BMCBEs reach the same SED, both BMCBEs will be suggested for the organisation to take into consideration.

Moreover, the intent of the tool is to give organisations a starting point to pursue further opportunities to establish a more circular conduct and at the same time seize benefits in the different dimensions of sustainability. The self-assessment tool provides guidance on what type of BMCBE should be pursued by the organisation based on the characteristics of the existing or desired BM reported by the representatives of the organisation using the tool. Based on the results of the tool, the suggested BMCBE is presented to the organisation along with its characteristics and potential strategies. This should be analysed by the organisation as a whole and it should be further studied how the BMCBE could be incorporated into their strategy.

The organisation might already have some of the characteristics of the suggested BMCBE in place. In such case, a further look can be taken to spot further opportunities within the BM that might have been overlooked.

Furthermore, a great concern with CE is the negative environmental impacts that might appear when establishing more circular systems, such as rebound effects and other resulting negative impacts. To avoid establishing systems that are only "more circular", it is suggested that the organisation conduct LCA studies to investigate (and communicate) the environmental performance of the system is and how circularity can be beneficial (thus increasing added value while lowering environmental impacts). On top of it, doing LCAs might also yield a good start to conquering an Environmental Product Declaration (EPD) for a product or family of products, which is a label that allows reporting the environmental impacts of a product system.

6 RESULTS AND DISCUSSIONS FROM TESTING THE TOOL - PHASE III

This Chapter describes the first use of the tool and the case study developed during such endeavour.

6.1 SUGGESTING A BMCBE TO ORGANISATION X BASED ON THE RESULTS OF THE TOOL

The BM at Organisation X already accounts for aspects of increased circularity, as their products are based on many waste flows, mainly from agriculture at the moment, but their feedstock is flexible, as different materials can be used as basis for their products, although resulting in different properties for each final product.

When using the tool, as it was guided by the researcher, the company representatives were asked whether they would like to assess the opportunities for their BM based on a current state of their business, where they could then focus on actions to be taken to strengthen their current BM in relation to circularity and spot opportunities based on their current vision, or a future state, where they could use the results to dwell on actions to be taken to bridge a potential gap between their business now and their desired vision of the business. The company representatives chose to assess their BM based on the current state of the organisation, for which the researcher requested them to keep this option in mind during the assessment.

After using the B2Circle tool to assess Organisation X's BM, the results presented a few inconsistencies (as addressed in section 3.3.1), which were, then, resolved. Table 33 shows the results for Organisation X's BM before and after resolving inconsistencies.

Table 33 - Ranking of BMCBEs for Organisation X

Business Model for a Circular Bioeconomy	Before resolving inconsistencies		After resolving inconsistencies	
	SED	rank	SED	rank
Establishing biorefineries	35.86	1	35.77	1
Value recovery from waste	39.79	5	36.42	2
Innovation towards bio- and renewable resources	37.30	2	37.55	3
Resource exchange	40.84	6	38.86	4
Optimising resource efficiency and use	38.10	3	38.91	5
Valuing the local economy	38.96	4	40.69	6
Service- and result-oriented offers	51.70	7	51.38	7

Source: Author (2021)

The results of the CR on the first and second assessments are presented in Table 34.

Table 34 - Consistency ratio (CR) for Organisation X’s BM after 1st and 2nd assessments

Building Block	Criterion	CR - Organisation X's BM - 1st assessment	CR - Organisation X's BM - 2nd assessment
Users and Contexts	Nature of offer	0.00	0.00
Users and Contexts	Final customer	0.00	0.00
Value proposition	Market strategy	0.32*	0.10
Value proposition	Production scale	0.00	0.00
Revenues	Nature of revenue	0.00	0.00
Revenues	Impact of revenue	0.00	0.00
Costs	Nature of costs	0.00	0.00
Costs	Origin of costs	0.00	0.00
Mission	Mission driver	0.12*	0.04
Key activities	Type of activity	0.15*	0.07
Partners	Type of partner	0.20*	0.06
Partners	Position of partner in the value chain	0.00	0.00
Natural resources	Origin of natural resources	0.00	0.00
Technical resources	Ownership of technical resources	0.20*	0.10
Energy resources	Origin of energy resources	0.00	0.00
Next use	End-of-life management	0.05	0.05
Distribution	Immediate customer	0.00	0.00
Positive Impacts	Dimension of positive impacts	0.00	0.00
Negative Impacts	Dimension of negative impacts	0.00	0.00

*CR shows inconsistent results

Source: Author (2021)

It can be noted the importance of resolving inconsistencies, since the results might vary to some extent. Nonetheless, the results that matter are the ones after the inconsistencies had been resolved. Therefore, “Establishing biorefineries” was the BMCBE recommended to Organisation X. Although the first and last positions in the rank did not change, all the remaining BMCBEs switched places in the list. It is clear that for Organisation X the best suited BMCBE for its current BM is “Establishing Biorefineries”, and that the BMCBE which is the furthest from their current BM is “Service- and result-oriented offers”.

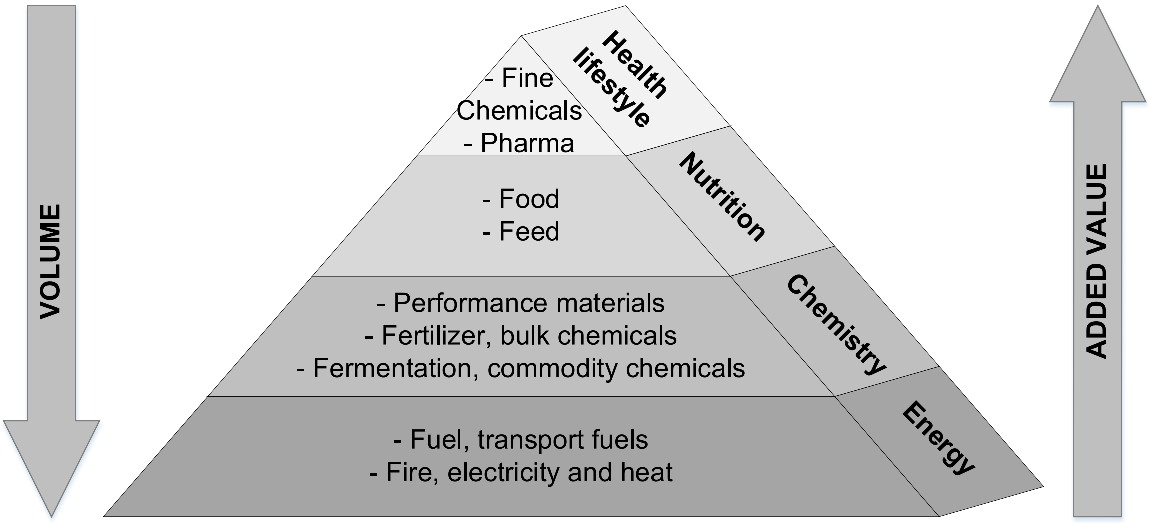
Recalling the characteristics of the BMCBE “Establishing biorefineries” (from section 4.4.4), it helps close and narrow resource flows by establishing facilities that can be shared between companies or product systems to make bioproducts in order to take advantage of using similar or the same resource streams or infrastructure.

Organisation X already has many of the elements of this BMCBE in practise, since their products can be made in cascaded systems and they help substitute other products that are either based on non-renewable feedstock or based on primary bioresources, i.e., which are in their first use.

When deploying this BMCBE, companies can share facilities or resources, form clusters or networks of companies, establish cooperatives and bioproduction parks, by engaging in collaborative efforts with partners in different places along the value chain, but especially with partners that are in the same or an immediately upstream or downstream position in relation to the organisation's operations. Moreover, a company making use of this BMCBE can act on its own by engaging in vertical or horizontal (and either upstream or downstream) integration of its production.

The concept of a biorefinery is based on collaboration and sharing both among organisations and among product systems. Thus, in the case of Organisation X, especially because they are still looking to scale-up their operations, it could be interesting for them to make their bioproducts in non-dedicated or shared facilities along with companies or product systems that are targeted to the same or different customer groups. Although they do not generate any kind of waste, as they are a start-up, it is also suggested for them to explore possibilities to diversify their business activities, taking into consideration the concept of biorefineries, based on insights that can be gained from the biomass value pyramid, illustrated in Figure 14.

Figure 14 - Biomass value pyramid



Source: Translated from translated from Verburg (2007)

In the case of engaging in sharing initiatives, they should bear in mind the main activities and resources for managing said shared facilities and resources (natural, technical, and energy), and focus on establishing sound partnerships for collaboration in operations, maintenance, and distribution channels, coordinating receipt and delivery of resources and products. Furthermore, it could be beneficial for them to engage in shared activities with partner companies when customer segments are the same or closely related to those targeted by the organisation.

Sharing facilities and/or operations (either between companies or between product systems) can bring down costs, as well as avoid wastes for managing transportation of supplies or final products to customers. Moreover, on top of lowering costs, it can result in increased environmental value by avoiding the excessive use of resources due to shared operations. Furthermore, setting into action these types of operations, the organisation might contribute to an array of SDGs, such as SDG 2, 6, 7, 8, 9, 12, 13, 14, and 15, as highlighted in Table 35 (page 137) (also refer to section 4.4.4).

Nonetheless, as aforementioned, Organisation X has not yet scaled-up, and one of the reasons is the lack of potential customer segments, which might be boosted by communicating more openly and effectively the environmental value (accounting for environmental externalities) of their value offer. This could be strengthened by conducting an LCA study to externalise the environmental sustainability value of their product (value offer), and to spot opportunities where they could lower the environmental impacts of their operations (especially via taking advantage of the proposed BMCBE).

Organisation X's leading product at the moment is a thermo-acoustic panel, which can be made in different shapes and sizes and can be used for decoration and/or sound and heat insulation purposes. In agreement with the representatives of Organisation X, it was decided to conduct an LCA of a typical thermo-acoustic panel. The LCA study for the typical thermo-acoustic panel made from bioresources is addressed in the next section.

Table 35 - SDGs and respective targets for the BMCBE *establishing biorefineries*

SDG		Targets
2	**Zero Hunger**	**2.4** By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
6	**Clean Water and Sanitation**	**6.3** By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
7	**Affordable and Clean Energy**	**7.2** By 2030, increase substantially the share of renewable energy in the global energy mix.
8	**Decent Work and Economic Growth**	**8.4** Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead.
9	**Industry, Innovation and Infrastructure**	**9.4** By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
12	**Responsible Consumption and Production**	**12.2** By 2030, achieve the sustainable management and efficient use of natural resources. **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. **12.4** By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment. **12.5** By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.
13	**Climate Action**	**13.3** Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning. **13.b** Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities * Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.
14	**Life Below Water**	**14.1** By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.
15	**Life on Land**	**15.3** By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world. **15.4** By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development.

Source: Author (2021)

6.2 LIFE CYCLE ASSESSMENT OF THERMO-ACOUSTIC PANELS

An LCA study should follow well-established standards, determined by ISO 14040 (ISO 2006a) and ISO 14044 (ISO 2006b), and comprises 4 phases: objective and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and interpretation. These phases and their results are presented hereafter.

6.2.1 Objective and Scope Definition

The objective of this LCA study was to determine the environmental impacts of the product system thermo-acoustic panel, from a cradle-to-gate perspective, i.e., considering from the extraction of raw materials from nature up to the moment the product is ready to leave the manufacturing facilities.

Regarding the functional unit (FU), as the product can be used with different intents, it was chosen to establish a declared unit (DU) rather than an FU in this study. The DU used in this study was 1kg of thermo-acoustic panel ready for distribution. For that reason, the reference flow chosen was 1kg of thermo-acoustic panel.

Further characteristics of the system under study are presented hereafter:

- Made from bio-based renewable material (mostly waste from agriculture);
- Biodegradable at the end-of-life;
- Low thermal conductivity;
- Combustion resistant (low potential for propagating fire, thus fire retardant);
- Thermal and acoustic insulator;
- Humidity resistant;
- Resistant to liquids and gases;
- Chemically inert;
- Does not emit toxic gases when in combustion.

6.2.2 Life Cycle Inventory

The LCI was built from specific (primary, measured), selected generic (direct match data from well-established/renowned databases), and proxy (adjusted/close proximity data from well-established/renowned databases, and data based on assumptions) data. Specific data was used in LCIs of the core processes, selected generic data and proxy data was used to model the upstream processes. To model upstream processes, a commercial licence of Ecoinvent v.7.3.1 was used, together with the database Agribalyse 3.0.1.

Core processes included the activities necessary for the production of the thermo-acoustic panel within the manufacturing gates. Upstream processes included the production of all input materials from “cradle” (i.e., since the moment the resources are extracted from nature) up to the moment the materials/products arrive at the manufacturing facilities. At the manufacturing facilities, inputs are used to produce a liquid medium, a solid medium, and a final process that includes both of the mediums mentioned and a few other inputs. The overall means for the production of the panels were introduced in section 3.3.2. Further information showing the specific processes and materials included within the system boundaries are not provided for trade secret reasons. Organisation X has a patent-pending technology, hence the specifics of their processes cannot be disclosed. The next section addresses the impact assessment.

6.2.3 Life Cycle Impact Assessment

Using as benchmark another study of a similar product, a cork agglomerate panel (LOPES, 2010), which has a function similar to that of the thermo-acoustic panel made by Organisation X, a few impact categories were chosen to be assessed. Recommendations on the methods to be used to assess each impact category were obtained from the international EPD® system (ENVIRONDEC, 2021). The categories and the respective methods used to calculate the impacts are shown in Table 36 (page 140).

Ten impact categories were assessed at midpoint level (i.e., immediate impacts). These midpoint categories provide the immediate impacts of the system.

Table 36 - Impact categories and the respective impact assessment methods

Life Cycle Impact Assessment Method	Impact Category (Midpoint)	Unit
IPCC 2013	Climate Change	kg CO_2-Eq
CML-IA baseline	Abiotic Depletion	kg Sb-Eq
CML-IA baseline	Eutrophication	kg PO_4--- Eq
CML-IA baseline	Ozone Layer Depletion	kg CFC-11-Eq
CML-IA non-baseline	Acidification	kg SO_2-Eq
ReCiPe Midpoint (H)	Freshwater Ecotoxicity	kg 1,4-DCB-Eq
ReCiPe Midpoint (H)	Human Toxicity	kg 1,4-DCB-Eq
ReCiPe Midpoint (H)	Marine Ecotoxicity	kg 1,4-DCB-Eq
ReCiPe Midpoint (H)	Terrestrial Ecotoxicity	kg 1,4-DCB-Eq
ReCiPe Midpoint (H)	Photochemical Oxidant Formation	kg NMVOC

Source: Author (2021)

The category of climate change assesses the infrared radiative forcing (W/m2) using the baseline model for 100 years of the Intergovernmental Panel on Climate Change (IPCC) (ISO 2006b). For climate change, the impacts were assessed according to the subcategories provided by the method used (IPCC), thus biogenic CO_2, fossil CO_2, CO_2 from land use change, and CO_2 uptake.

The category of abiotic depletion is an indicator of use/extraction of mineral and fossil resources. It accounts for the availability of water in fossil reserves and the rate of use and renewability of these reserves, relative to the reserves of antimony (abiotic resource of reference) (CANALS *et al.,* 2009).

The category of eutrophication is an indicator of phosphorus. It addresses the impacts caused by the load of phosphorus thrown into the system (UGAYA *et al.,* 2019).

The category of ozone layer depletion is an indicator of the concentration of trichlorofluoromethane and other chlorofluorocarbons (CFCs). It comprises a simplified means to determine the ability of a chemical to destroy ozone (WUEBBLES, 2015).

The category of acidification is an indicator of H+ ions. It addresses the impacts relative to the processes that lead to higher acidity in water systems and the soil due to the concentration of hydrogen ions (MENDES, 2013).

The category of photochemical oxidant formation is an indicator of ethylene equivalents. It accounts for the potential of photochemical ozone formation of each substance emitted into the air (DERWENT *et al.,* 1998).

The categories of freshwater, human, marine, and terrestrial ecotoxicity are indicators of the concentration of 1,4 dichlorobenzene. They account for the toxicological effects of a chemical emitted into the environment that imply a cause–effect chain (ROSENBAUM *et al.,* 2008).

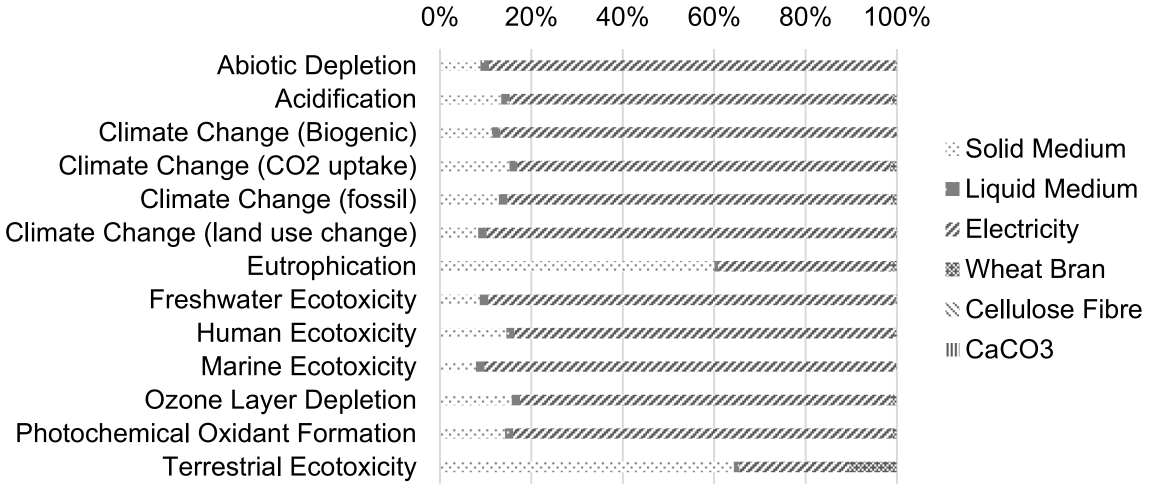
The environmental performance of the system under study, according to the 10 impact categories assessed, is summarised in Table 37 and Graph 3**Error! Reference source not found.**.

Table 37 - Results of LCA of thermo-acoustic panel

Method	Impact Category (Midpoint)	Unit	Result (1kg of panel)
CML-IA non-baseline	Acidification	kg SO_2-Eq	6.88E-03
IPCC 2013	Climate Change (biogenic)	kg CO_2-Eq	8.88E-01
	Climate Change (fossil)	kg CO_2-Eq	6.47E-01
	Climate Change (CO_2 uptake)	kg CO_2-Eq	-7.53E-01
	Climate Change (land use change)	kg CO_2-Eq	1.58E-01
CML-IA baseline	Abiotic Depletion	kg Sb-Eq	2.17E-05
	Eutrophication	kg PO_4--- Eq	4.01E-03
	Ozone layer depletion	kg CFC-11-Eq	3.43E-08
ReCiPe Midpoint (H)	Freshwater Ecotoxicity	kg 1,4-DCB-Eq	1.47E-01
	Human Toxicity	kg 1,4-DCB-Eq	3.86E-01
	Marine Ecotoxicity	kg 1,4-DCB-Eq	1.25E-01
	Photochemical Oxidant Formation	kg NMVOC	3.09E-03
	Terrestrial Ecotoxicity	kg 1,4-DCB-Eq	3.12E-04

Source: Author (2021)

Graph 3 - Life cycle impact assessment for thermo-acoustic panel



Source: Author (2021)

The greatest hotspot, contributing the most to the total impacts is electricity. This behaviour is noted across all impact categories, where it contributed to more than 80% of total impacts.

Besides the electricity that is consumed in the final step of the production of the panels, the second hotspot is the solid medium, where once again electricity is the main contributor to total impacts, followed by the use of wheat bran and waste wood. This behaviour can be observed in all impact categories, except for eutrophication and terrestrial ecotoxicity.

For the category eutrophication, the hotspot is the solid medium, where the main contributor is the use of waste wood. Only the second hotspot in this category is the use of electricity in the final step of producing the panels. For terrestrial ecotoxicity, the solid medium also accounts for the main hotspot, but the main contributor in this case is the use of wheat bran, and once again, only the second hotspot is the use of electricity in the final step of producing the panels.

6.2.4 Interpretation and Conclusions of the LCA Study

The objective of this LCA was to define the environmental profile of the impacts of the product system thermo-acoustic panel and communicate such results. Nonetheless, a few improvement measures can be drawn from those results and suggested to Organisation X, based on the hotspots found during the LCIA phase.

The main hotpots for the product system assessed in this LCA were the use of electricity in the final stage of producing the thermo-acoustic panels, and the solid medium. In the solid medium, the components which contributed the most to environmental impacts of the system were the consumption of electricity and the use of wheat bran.

Overall, it is observed that solely reducing the consumption of electricity at the final stage of the production of the panels can contribute to reducing the environmental impacts of the system to a large extent. It is noted that scaling-up the production and using less energy-intensive equipment, or sharing equipment/facilities at this stage, might be able to reduce the net energy consumption and lower the need for energy per product unit. This measure can be achieved by setting into action novel practises from the BMCBE identified as the most suitable for Organisation X, *Establishing biorefineries*, of which some features are already in practise by the organisation.

6.3 FURTHER DISCUSSIONS ON THE RESULTS FROM THE TESTING OF THE TOOL

The content in section 6.1 helped achieve specific objectives v, vi, vii, and viii. The B2Circle tool served the purpose of identifying the BMCBE that best fit the BM profiled by Organisation X (according to the 19 criteria) and presented the organisation representatives with the characteristics of said BM. The B2Circle tool brought to light a structure that could be adopted by the organisation and how the organisation could define their value proposition, creation and delivery, and capture, in order to establish their BM around greater circularity within a BE context, by means of biorefineries. Nonetheless, the tool does not mandate how the organisation should do it from tactical and operational viewpoints, as doing so would make the tool context specific, and of narrow application.

A few further recommendations were left for Organisation X, however they also apply to all users of the B2Circle tool, regardless of the BMCBE suggested to the organisation, as follows:

a) Even if the organisation already has some or all of the characteristics of the suggested BMCBE in place, it is recommended that the organisation revisit its BM checking for further opportunities for increased circularity following the characteristics of the suggested BMCBE;
b) The organisation should analyse their product(s) system(s) based on the suggested BMCBE in order to verify the potential for increased circularity at different levels, in the following sequence: material, component, product, service, socio-technical aspects;
c) In case of designing a new BM, or redesigning any part of their existing BM, the organisation should analyse their value chain for undesired effects of the increased circularity resulted from their product(s) system(s);
d) The organisation should analyse the use of feedstock and the end-of-life of their product(s) system(s) and bear in mind the selection of feedstock (and suppliers) and the principle of designing out waste taking into consideration the biomass value pyramid (refer to Figure 14, on page 135) in order to

establish systems that are truly more circular and enable the use of resources for longer within technical loops;

e) The organisation should further investigate their BM through a more circular lens by depicting their BM seeking to incorporate the characteristics of the recommended BMCBE using the Circular Canvas framework;
f) The organisation should conduct an analysis of the environmental impacts of their product system (e.g., by means of an LCA) to guide their actions towards greater circularity and lower environmental impacts (in the case of Organisation X, this was done by the researcher, as seen in section 6.2);
g) The organisation should seek further development of the measures according to the suggested BMCBE and the conclusions reached by the aforementioned analyses by seeking advice from knowledgeable sources or third-party consultancy.

Moreover, a few other recommendations, tailored to Organisation X, could be reached, as follows:

h) Considering the biomass value pyramid, the LCA study conducted for the thermo-acoustic panels, and the context of biorefineries (also refer to C-15, in Table 10, and D9, in Table 11), it is suggested that Organisation X assess the possibility of producing their panels with different feedstocks throughout the year, assessing the environmental and circularity impacts, and the impacts for their business (e.g. differences in physical-mechanical properties of the panels) of different feedstocks (e.g., different types of agricultural waste, or even wastes from other origins other than agriculture), and use such results to communicate their circular/environmental performance to stakeholders;
i) It is suggested that Organisation X investigate replacing the equipment they use in the final stage of the production of panels seeking greater energy efficiency and/or replace the energy source used to power such equipment in order to lower environmental impacts. An alternate route would be partnering with a collaborator to either share the more energy-efficient equipment or share the less-impacting energy source.

A summary with all key information presented in this Chapter has been sent to Organisation X in the form of a report and a meeting was held to discuss it.

Lastly, in summary, the following will be shown as results for an organisation using the B2Circle tool:

i. The BMCBE recommended;

ii. The characteristics of the recommended BMCBE, i.e., a description of the BMCBE as per its characteristics of value offer, value creation and delivery, and value capture, as well as the example strategies as defined in sections 4.4.1 through 4.4.7;

iii. The SDGs and respective targets the organisation can potentially contribute to by establishing their business around the recommended BMCBE (a complete table as per the one provided to Organisation X, for the respective BMCBE) (see Table 35);

iv. General recommendations a) through g), also showing the biomass value pyramid alongside d) and the Circular Canvas alongside e).

7 FINAL REMARKS

This Chapter presents the final remarks of this dissertation, including the main conclusions, limitations, and opportunities for further research.

7.1 MAIN CONCLUSIONS

The methods used to conduct this dissertation were successful in guiding sound literature and practise reviews, the proposal of procedures to validate externally a number of criteria (and the alternatives among them), the profiling of seven BMCBEs, as well as a procedure to compare the characteristics of the BM of an organisation to those of the BMCBEs in the proposed taxonomy. All of this culminated in the proposal of the B2Circle tool. The methods used allowed to reach the aims of this research by building a tool directed to the BE. However, by being proven successful these methods can also be applied to other sectors, specific industries, or even other areas of knowledge.

The theoretical contributions, and thus the academic impact, of this dissertation are a few. They include the detailed knowledge of the aspects that influence businesses in a circular bioeconomy, as per the barriers, challenges, drivers, and opportunities encountered by them. Another contribution is the taxonomy for BMCBEs, which unveils the characteristics of different BMs within the CBE realm, their aspects of value proposition, creation and delivery, and capture, and the SDGs and specific targets businesses making use of them can contribute to.

The practical and managerial contributions are linked to the theoretical ones to some extent. The results of this dissertation, especially by making use of the tool, can guide organisations to start a journey towards a circular business, or adapt their BM to include strategies and practises that allow them to be more circular and lower the environmental impacts of their operations and value chains. What is more, this dissertation and the B2Circle tool contribute to raising awareness of the potential of the BE to a more circular economy where a range of businesses can acquire knowledge and insights on the many benefits that can be reaped (both from an environmental and economic perspectives) by engaging in CBE practises.

Furthermore, the results of this dissertation and the B2Circle tool shed light on the need (and untapped potential) for governments to create incentives for businesses to transition to the use of biological and renewable resources and help develop a CBE. This is especially true to Brazil, where this dissertation was developed, for the great potential for a BE and a CBE in the country. Nevertheless, the greatest contribution, the innovation/novelty of this research, and thus the potential for knowledge transfer, can be summarised in the recommendation of a BMCBE to be adopted by a BE business, taking into consideration the characteristics of the BM of the organisation as well as its desire either to encounter a path to adapt its current BM in the search for greater circularity or to guide it to achieve the recommended BMCBE based on a future vision of its business.

The economic and environmental impacts that might be generated by this dissertation lie in the potential for the development of a CBE in the following decades, especially with the increasing need to transition to the use of renewable resources, thus replacing fossil-based materials and products with renewable ones and building infrastructure that supports the sustainable exploration of such resources. The social impacts generated by this research lie in fomenting the adoption of operations and practises that are nature-inspired and based on renewable resources, raising awareness and shaping the behaviour of both organisations and customers to transition to a more responsible production and consumption of products in a CBE.

Furthermore, the first use of the B2Circle tool proved it to be successful in identifying the business approach of an organisation (Organisation X) and recommending a BMCBE that suited well the organisation using the tool. The characteristics of the BMCBE recommended by the tool and the general recommendations allowed generating specific recommendations to Organisation X, which were relevant to its operations and raised the interest of its representatives. The results and recommendations were presented to Organisation X, and they are currently under analysis and/or implementation.

7.2 LIMITATIONS

This dissertation does not claim to be exhaustive nor exempt from limitations. Hence, aiming to bring transparency, the limitations of this study are reported hereafter.

The results from the literature and practise reviews were based on the searches conducted using the specific terms and databases described in the methods section as well as on the organisations that agreed to participate based on the convenience sampling described. In addition, the barriers, challenges, drivers, and opportunities for businesses in a CBE were presented on a general/generic approach. Each of those aspects might take place (or not) differently depending on the context, and their definition and perceived need might also vary depending on the stakeholder (e.g., business, consumer, or government).

The proposed taxonomy for BMCBEs was based on the expertise resulting from the literature and practise reviews, and although the list of overarching BMCBEs is believed to represent the existing BMCBEs, the list cannot be said to be exhaustive, as innovation and knowledge in the area evolve quickly.

The B2Circle tool was based on the use of FAHP for ranking the alternatives within a criterion, for a building block in a BMCBE, and the Euclidean distance was deemed adequate to account for the comparison between the BM of an organisation using the tool and each of the proposed overarching BMCBEs. Nonetheless, although these methodological choices were adequately justified, no other methods were tested for such comparison.

The B2Circle tool is directed to businesses working within or that desire to transition or start their operations within a BE. Nonetheless, its recommendations can also be used, on a general approach, by businesses in other environments that want to pursue a circular path. Nevertheless, although tailored to BE businesses, the tool provides general recommendations that are not specific to certain types of businesses, thus fulfilling the intent of being within reach to any organisation operating in the BE environment, for general recommendations can be tailored more easily than specific recommendations can be generalized.

The testing of the tool occurred through only one use, its first use. Thus, further testing is recommended, and the final interface of the tool is yet to be defined. The first use of the tool was guided by the researcher, but the tool is to be operated by the user only. A number of uses is still needed for further analyses of the best interface allowing the tool to be operated entirely by the user for the self-assessment and provision of results.

7.3 OPPORTUNITIES FOR FURTHER RESEARCH

The investigation of synergies among the aspects (barriers, challenges, drivers, and opportunities) that were presented in this research is left as a suggestion for further research. There might barriers and/or challenges that will take place concomitantly. The same is true for drivers and opportunities. Moreover, there might be drivers and/or opportunities that when coming into place at the same time might offset a challenge or a barrier, as well as there might be barriers and/or challenges that might prevent businesses from seizing certain opportunities or benefiting from drivers. Thus, those potential synergies are left for investigation in future research endeavours.

It is also suggested that further strategies be listed for each of the BMCBEs in the taxonomy proposed, increasing the potential opportunities that might be spotted and set into practise by an organisation using the tool. Moreover, the B2Circle tool certainly can benefit from further tailoring the BMCBEs to specific sectors and only then provide specific guidance on what day-to-day practises could be adopted to implement a more circular conduct. Therefore, adaptations of the tool could be made to help provide more detailed results to specific sectors. Examples from real businesses (e.g., from the cases in the practise review) could be added to the final version of the tool as resources for consultation and examples as to how to implement CBE practises and how they could unfold.

The B2Circle tool should gain an online version to be available to prospective users, and its use should be further tailored to allow remote use, treatment of data, and report of results. The logic behind the B2Circle tool has been fully developed, however its final interface and where it is to be hosted for open access is a matter yet to be pursued, as it needs further collaboration, funding, and knowledge from other areas to make it finally come to life.

The results provided to Organisation X regarding the possibility of further analysis of their BM and the implementation of potential improvement measures could not be overseen and followed up by the researcher, and they were left at the organisation’s discretion, since the researcher had his defence scheduled soon after the results from the B2Circle tool were generated. A qualitative (regarding circularity) and quantitative (regarding the environmental impacts of the improved system) analysis of the measures implemented by Organisation X, deriving from the results of the B2Circle tool, is left as a suggestion for future research.

Lastly, this dissertation also helped reveal a number of research questions that are yet to be explored, which include:

- What are the different implications for the implementation and management of BMCBEs for micro, small, medium, and large organisations?
- What are the most effective incentives that can be given to organisations by governmental initiatives to foment the development of a CBE?
- What are the most commonly adopted BMCBEs by BE organisations and why?
- Which of the overarching BMCBEs within the proposed taxonomy yield the least environmental impacts and which yield the lowest costs or highest profit for the business?
- What are the main social aspects that influence the implementation and management of different BMCBEs both within the organisation and in the relationship with customers?

REFERENCES

ALEXANDRI, M.; LOPEZ-GOMEZ, J. P.; OLSZEWSKA-WIDDRAT, A.; VENUS, J. Valorising Agro-industrial Wastes within the Circular Bioeconomy Concept: the Case of Defatted Rice Bran with Emphasis on Bioconversion Strategies. **Fermentation**, v. 6, n. 2, 2020. https://doi.org/10.3390/fermentation6020042

AMIT; DAHIYA, D.; GHOSH, U. K.; NIGAM, P. S. et al. Food industries wastewater recycling for biodiesel production through microalgal remediation. **Sustainability**, v. 13, n. 15, 2021. https://doi.org/10.3390/su13158267

ANGOURIA-TSOROCHIDOU, E.; TEIGISEROVA, D. A.; THOMSEN, M. Limits to circular bioeconomy in the transition towards decentralized biowaste management systems. **Resources, Conservation and Recycling**, v. 164, p. 105207, 2021. https://doi.org/10.1016/j.resconrec.2020.105207

AWASTHI, M. K. et al. A critical review of organic manure biorefinery models toward sustainable circular bioeconomy: Technological challenges, advancements, innovations, and future perspectives. **Renewable and Sustainable Energy Reviews**, v. 111, p. 115-131, 2019. https://doi.org/10.1016/j.rser.2019.05.017

AWASTHI, M. K.; SARSAIYA, S.; PATEL, A.; JUNEJA, A. et al. Refining biomass residues for sustainable energy and bio-products: An assessment of technology, its importance, and strategic applications in circular bio-economy. **Renewable and Sustainable Energy Reviews**, v. 127, p. 109876, 2020. https://doi.org/10.1016/j.rser.2020.109876

AZAM, A.; RAFIQ, M.; SHAFIQUE, M.; YUAN, J. Renewable electricity generation and economic growth nexus in developing countries: An ARDL approach. **Economic Research-Ekonomska Istraživanja**, v. 34, n. 1, p. 2423-2446, 2021. https://doi.org/10.1080/1331677X.2020.1865180

BANU, J. R.; KAVITHA, S.; KANNAH, R. Y.; KUMAR, M. D.; PREETHI; ATABANI, A. E.; KUMAR, G. Biorefinery of spent coffee grounds waste: Viable pathway towards circular bioeconomy. **Bioresource Technology**, v. 302, p. 122821, 2020. https://doi.org/10.1016/j.biortech.2020.122821

BANU, J. R.; PREETHI; KAVITHA, S.; GUNASEKARAN, M.; KUMAR, G. Microalgae based biorefinery promoting circular bioeconomy-techno economic and life-cycle analysis. **Bioresource Technology**, v. 302, p. 122822, 2020. https://doi.org/10.1016/j.biortech.2020.122822

BARAK, S.; MOKFI, T. Evaluation and selection of clustering methods using a hybrid group MCDM. **Expert Systems With Applications**, v. 138, p. 112817, 2019. https://doi.org/10.1016/j.eswa.2019.07.034

BARCELOS, S. M. B. D.; SALVADOR, R.; BARROS, M. V.; DE FRANCISCO, A. C. et al. Circularity of Brazilian silk: Promoting a circular bioeconomy in the production of silk cocoons. **Journal of Environmental Management**, v. 296, p. 113373, 2021. https://doi.org/10.1016/j.jenvman.2021.113373

BARROS, M. V.; SALVADOR, R.; DE FRANCISCO, A. C.; PIEKARSKI, C. M. Mapping of research lines on circular economy practices in agriculture: From waste to energy. **Renewable and Sustainable Energy Reviews**, v. 131, p. 109958, 2020. https://doi.org/10.1016/j.rser.2020.109958

BEHERA, B.; VENKATA SUPRAJA, K.; PARAMASIVAN, B. Integrated microalgal biorefinery for the production and application of biostimulants in circular bioeconomy. **Bioresource Technology**, v. 339, p. 125588, 2021. https://doi.org/10.1016/j.biortech.2021.125588

BENYUS, J. M. **Biomimicry:** Innovation inspired by nature: Morrow New York 1997.

BERBEL, J.; POSADILLO, A. Review and analysis of alternatives for the valorisation of agro-industrial olive oil by-products. **Sustainability**, v. 10, n. 1, 2018. https://doi.org/10.3390/su10010237

BIAN, B.; BAJRACHARYA, S.; XU, J.; PANT, D.; Saikaly, P. E. Microbial electrosynthesis from CO2: Challenges, opportunities and perspectives in the context of circular bioeconomy. **Bioresource Technology**, 302, p. 122863, 2020. https://doi.org/10.1016/j.biortech.2020.122863

BIO-BASED INDUSTRIES CONSORTIUM. The Bio-based Industries A Public-Private Partnership On Bio-Based Industries Vision: Accelerating innovation and market uptake of bio-based products. 2012. Available at: <http://biconsortium.eu/sites/biconsortium.eu/files/downloads/BIC_BBI_Vision_web.pdf>. Accessed 14 Nov 2021.

BJÖRKDAHL, J.; BÖRJESSON, S. Organizational climate and capabilities for innovation: a study of nine forest-based Nordic manufacturing firms. **Scandinavian Journal of Forest Research**, v. 26, n. 5, p. 488-500, 2011. https://doi.org/10.1080/02827581.2011.585997

BOCKEN, N.M.P., PAUW, I., BAKKER, C., VAN DER GRINTEN, B. Product design and business model strategies for a circular economy. **Journal of Industrial and Production Engineering**, v. 33, n. 5, p. 308-320, 2016. https://doi.org/10.1080/21681015.2016.1172124.

BOCKEN, N. M.; RITALA, P.; HUOTARI, P. The circular economy: exploring the introduction of the concept among S&P 500 firms. **Journal of Industrial Ecology**, v. 21, n. 3, p. 487-490, 2017. https://doi.org/10.1111/jiec.12605

BOCKEN, N. M.; SHORT, S. W.; RANA, P.; EVANS, S. A literature and practice review to develop sustainable business model archetypes. **Journal of Cleaner Production**, v. 65, p. 42-56, 2014. https://doi.org/10.1016/j.jclepro.2013.11.039

BOLWIG, S. et al. **Beyond animal feed? The valorisation of brewers' spent grain**. From Waste to Value: Valorisation Pathways for Organic Waste Streams in Circular Bioeconomies, 2019. https://doi.org/10.4324/9780429460289

BOS, H. L.; BROEZE, J. Circular bio-based production systems in the context of current biomass and fossil demand. **Biofuels, Bioproducts and Biorefining**, 14, n. 2, p. 187-197, 2020. https://doi.org/10.1002/bbb.2080

BOUDET, H.; ZANOCCO, C.; STELMACH, G.; MUTTAQEE, M.; FLORA, J. Public preferences for five electricity grid decarbonization policies in California. **Review of Policy Research,** v. 38, n. 5, p. 510-528, 2021. https://doi.org/10.1111/ropr.12442

BOULDING, K. E. **The economics of the coming spaceship Earth**. New York, 1966.

BRANDÃO, A. S.; GONÇALVES, A.; SANTOS, J. M. R. C. A. Circular bioeconomy strategies: From scientific research to commercially viable products. **Journal of Cleaner Production**, v. 295, 2021. https://doi.org/10.1016/j.jclepro.2021.126407

BRUNNHOFER, M.; GABRIELLA, N.; SCHOGGL, J. P.; STERN, T.; POSCH, A. The biorefinery transition in the European pulp and paper industry - A three-phase Delphi study including a SWOT-AHP analysis. **Forest Policy and Economics**, v. 110, 2020. https://doi.org/10.1016/j.forpol.2019.02.006

BSI (British Standards Institution). **BS 8001** - The rise of the Circular Economy. Available at: <https://www.bsigroup.com/en-GB/standards/benefits-of-using-

standards/becoming-more-sustainable-with-standards/BS8001-Circular-Economy/>, 2017. Accessed November 01 2021.

BUGGE, M. M.; BOLWIG, S.; HANSEN, T.; TANNER, A. N. **Theoretical perspectives on innovation for waste valorisation in the bioeconomy**. In: From Waste to Value: Valorisation Pathways for Organic Waste Streams in Circular Bioeconomies: Taylor and Francis, 2019. p. 51-70. https://doi.org/10.4324/9780429460289

CAMPUZANO, R.; GONZÁLEZ-MARTÍNEZ, S. Characteristics of the organic fraction of municipal solid waste and methane production: A review. **Waste Management**, v. 54, p. 3-12, 2016. https://doi.org/10.1016/j.wasman.2016.05.016

CANALS, L. M.; CHENOWETH, J.; CHAPAGAIN, A.; ORR, S.; ANTÓN, A.; CLIFT, R. Assessing freshwater use impacts in LCA: part I - inventory modelling and characterisation factors for the main impact pathways. **The International Journal of Life Cycle Assessment**, v.14, n. 1, p. 28–42, 2009. https://doi.org/10.1007/s11367-008-0030-z

CARRARESI, L.; BRORING, S. How does business model redesign foster resilience in emerging circular value chains? **Journal of Cleaner Production**, v. 289, p. 125823, 2021. https://doi.org/10.1016/j.jclepro.2021.125823

CARUS, M.; DAMMER, L. The circular bioeconomy – concepts, opportunities, and limitations. **Industrial biotechnology**, v. 14, n. 2, p. 83-91, 2018. https://doi.org/10.1089/ind.2018.29121.mca

CATONE, C. M.; RIPA, M.; GEREMIA, E.; ULGIATI, S. Bio-products from algae-based biorefinery on wastewater: A review. **Journal of Environmental Management**, 293, p. 112792, 2021. https://doi.org/10.1016/j.jenvman.2021.112792

CHAN, F.T.S., KUMAR, N., TIWARI, M.K., LAU, H.C.W., CHOY, K.L. Global supplier selection: a fuzzy-AHP approach. **International Journal of Production Research**, v. 46, n. 14, p. 3825–3857, 2008. http://dx.doi.org/10.1080/00207540600787200

CHANDRASEKHAR, K.; KUMAR, S.; LEE, B. D.; KIM, S. H. Waste based hydrogen production for circular bioeconomy: Current status and future directions. **Bioresource Technology**, 302, p. 122920, 2020. https://doi.org/10.1016/j.biortech.2020.122920

CHANG, S. C.; TSAI, P. H.; CHANG, S. C. A hybrid fuzzy model for selecting and evaluating the e-book business model: A case study on Taiwan e-book firms. **Applied Soft Computing**, v. 34, p. 194-204, 2015. https://doi.org/10.1016/j.asoc.2015.05.011

CHENG, S. Y.; TAN, X.; SHOW, P. L.; RAMBABU, K.; BANAT, F.; VEERAMUTHU, A.; LAU, B. F.; NG, E. P.; LING, T. C. Incorporating biowaste into circular bioeconomy: A critical review of current trend and scaling up feasibility. **Environmental Technology & Innovation**, 19, p. 101034, 2020. https://doi.org/10.1016/j.eti.2020.101034

CHOWDHARY, P.; GUPTA, A.; GNANSOUNOU, E.; PANDEY, A. CHATURVEDI, P. Current trends and possibilities for exploitation of Grape pomace as a potential source for value addition. **Environmental Pollution**, 278, 2021. https://doi.org/10.1016/j.envpol.2021.116796

CIRCULAB. **The Circular Canvas**: The tool to design regenerative business models. Available at: <https://circulab.com/toolbox-circular-economy/circular-canvas-regenerative-business-models/>. Accessed: 09 out. 2021.

CLAUSER, N. M.; GONZÁLEZ, G.; MENDIETA, C. M.; KRUYENISKI, J.; AREA, M. C.; VALLEJOS, M. E. Biomass waste as sustainable raw material for energy and fuels. **Sustainability**, 13, n. 2, p. 1-21, 2021. https://doi.org/10.3390/su13020794

CLAYTON, M. J. Delphi: a technique to harness expert opinion for critical decision-making tasks in education. **Educational Psychology**, v. 17, n. 4, p. 373-386, 1997. https://doi.org/10.1080/0144341970170401

COMMONER, B**. The Closing Circle:** Nature. Man and Technology, p. 11-44, 1971.

COPPOLA, D.; LAURITANO, C.; PALMA ESPOSITO, F.; RICCIO, G. et al. Fish Waste: From Problem to Valuable Resource. **Marine drugs**, 19, n. 2, 2021. https://doi.org/10.3390/md19020116

CORCORAN, A. A.; HUNT, R. W. Capitalizing on harmful algal blooms: From problems to products. **Algal Research**, 55, p. 102265, 2021. https://doi.org/10.1016/j.algal.2021.102265

DAHAL, R. K.; ACHARYA, B.; FAROOQUE, A. Biochar: a sustainable solution for solid waste management in agro-processing industries. **Biofuels**, 12, n. 2, p. 237-245, 2021. https://doi.org/10.1080/17597269.2018.1468978

DAHIYA, S.; KUMAR, A. N.; SRAVAN, J. S.; CHATTERJEE, S.; SARKAR, O.; MOHAN, S. V. Food waste biorefinery: Sustainable strategy for circular bioeconomy. **Bioresource Technology**, v. 248, p. 2-12, 2018. https://doi.org/10.1016/j.biortech.2017.07.176

DALKEY, N.; HELMER, O. An experimental application of the Delphi method to the use of experts. **Management Science**, vol. 9, n. 3, p. 458–467, 1963.

D'AMATO, D.; DROSTE, N.; ALLEN, B.; KETTUNEN, M.; LÄHTINEN, K.; KORHONEN, J.; LESKINEN, P.; MATTHIES, B. D.; TOPPINEN, A. Green, circular, bio economy: A comparative analysis of sustainability avenues. **Journal of Cleaner Production**, v. 168, p. 716-734, 2017. https://doi.org/10.1016/j.jclepro.2017.09.053

D'AMATO, D.; VEIJONAHO, S.; TOPPINEN, A. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. **Forest Policy and Economics**, v. 110, p. 101848, 2020. https://doi.org/10.1016/j.forpol.2018.12.004

DE LAPORTE, A. V.; WEERSINK, A. J.; MCKENNEY, D. W. Effects of supply chain structure and biomass prices on bioenergy feedstock supply. **Applied energy**, v. 183, p. 1053-1064, 2016. https://doi.org/10.1016/j.apenergy.2016.09.049

DEBOER, J.; PANWAR, R.; KOZAK, R.; CASHORE, B. Squaring the circle: Refining the competitiveness logic for the circular bioeconomy. **Forest Policy and Economics**, 110, p. 101858, 2020. https://doi.org/10.1016/j.forpol.2019.01.003

DELBECQ, A.L.; VAN DE VEN, A.H.; GUSTAFSON, D.H. 1975. **Group Techniques for Program Planning: A Guide to Nominal Groups and Delphi Process**. Scott Foresman Company, Glenview, Illinois.

DERWENT, R. G.; JENKIN, M. E.; SAUNDERS, S. M.; PILLING, M. J. Photochemical ozone creation potentials for organic compounds in northwest Europe calculated with a master chemical mechanism. **Atmospheric environment**, v. 32, n. 14-15, p. 2429-2441, 1998. https://doi.org/10.1016/S1352-2310(98)00053-3

DONNER, M.; DE VRIES, H. How to innovate business models for a circular bio-economy? **Business Strategy and the Environment**, 30, n. 4, p. 1932-1947, 2021. https://doi.org/10.1002/bse.2725

DONNER, M.; GOHIER, R.; DE VRIES, H. A new circular business model typology for creating value from agro-waste. **Science of The Total Environment**, 716, p. 137065, 2020. https://doi.org/10.1016/j.scitotenv.2020.137065

DONNER, M.; RADIC, I. Innovative Circular Business Models in the Olive Oil Sector for Sustainable Mediterranean Agrifood Systems. **Sustainability**, 13, n. 5, 2021. https://doi.org/10.3390/su13052588

DONNER, M.; VERNIQUET, A.; BROEZE, J.; KAYSER, K.; VRIES, H. Critical success and risk factors for circular business models valorising agricultural waste and by-products. **Resources Conservation and Recycling**, v. 165, p. 105236, 2021. https://doi.org/10.1016/j.resconrec.2020.105236

DUAN, Y.; PANDEY, A.; ZHANG, Z.; AWASTHI, M. K.; BHATIA, S. K.; TAHERZADEH, M. J. Organic solid waste biorefinery: Sustainable strategy for emerging circular bioeconomy in China. **Industrial Crops and Products**, v. 153, p. 112568, 2020. https://doi.org/10.1016/j.indcrop.2020.112568

DUARTE, E.; FRAGOSO, R.; SMOZINSKI, N.; TAVARES, J. Enhancing bioenergy recovery from agro-food biowastes as a strategy to promote circular bioeconomy. **Journal of Sustainable Development of Energy, Water and Environment Systems**, 9, n. 1, p. 1-13, 2021. https://doi.org/10.13044/j.sdewes.d8.0320

DUQUE-ACEVEDO, M.; BELMONTE-URENA, L. J.; PLAZA-UBEDA, J. A.; CAMACHO-FERRE, F. The Management of Agricultural Waste Biomass in the Framework of Circular Economy and Bioeconomy: An Opportunity for Greenhouse Agriculture in Southeast Spain. **Agronomy**, 10, n. 4, 2020a. https://doi.org/10.3390/agronomy10040489

DUQUE-ACEVEDO, M.; BELMONTE-URENA, L. J.; YAKOVLEVA, N.; CAMACHO-FERRE, F. Analysis of the Circular Economic Production Models and Their Approach in Agriculture and Agricultural Waste Biomass Management. **International Journal of Environmental Research and Public Health**, 17, n. 24, 2020b. https://doi.org/10.3390/ijerph17249549

EGEA, F. J.; TORRENTE, R. G.; AGUILAR, A. An efficient agro-industrial complex in Almería (Spain): Towards an integrated and sustainable bioeconomy model. **New Biotechnology**, v. 40, p. 103-112, 2018. https://doi.org/10.1016/j.nbt.2017.06.009

EGELYNG, H. et al. Cascading Norwegian co-streams for bioeconomic transition. **Journal of Cleaner Production**, v. 172, p. 3864-3873, 2018. https://doi.org/10.1016/j.jclepro.2017.05.099

EMF. **Cities and Circular Economy for Food**. Ellen MacArthur Foundation: Cowes, UK, 2019.

EMF. **Cities in the Circular Economy**: An initial Exploration. Ellen MacArthur Foundation: Cowes, UK, 2017a.

EMF. **Delivering the circular economy**: A Toolkit for Policy Makers. Ellen MacArthur Foundation: Cowes, UK, 2015.

EMF. **Financing the circular economy**: Capturing the opportunity. Ellen MacArthur Foundation: Cowes, UK, 2020a.

EMF. **Measure business circularity:** Circulytics. Ellen MacArthur Foundation: Cowes, UK, 2021a.

EMF. **The big food redesign**: Regenerating Nature with the Circular Economy. Ellen MacArthur Foundation: Cowes, UK, 2021b.

EMF. **The circular economy**: a transformative Covid-19 recovery strategy: How policymakers can pave the way to a low carbon, prosperous future. Ellen MacArthur Foundation: Cowes, UK, 2020b.

EMF. **The New Plastics Economy**: Rethinking the Future of Plastics. Ellen MacArthur Foundation: Cowes, UK, 2016.

EMF. **Towards the circular economy, economic and business rationale for an accelerated transition**. Ellen MacArthur Foundation: Cowes, UK, 2013.

EMF. **Universal circular economy policy goals**: Enabling the transition to scale. Ellen MacArthur Foundation: Cowes, UK, 2021c.

EMF. **Urban Biocycles**. Ellen MacArthur Foundation: Cowes, UK, 2017b.

EMOVON, I.; NORMAN, R.A.; MURPHY, A.J. 2018. Hybrid MCDM based methodology for selecting the optimum maintenance strategy for ship machinery systems. **Journal of Intelligent Manufacturing**, v. 29, p. 519–531. https://doi.org/10.1007/s10845-015-1133-6.

ENRIQUEZ, J. **Genomics and the World's Economy**. American Association for the Advancement of Science 1998.

ENVIRONDEC. **Impact Indicators**. Accessed 31 October 2021. Available at: <https://www.environdec.com/resources/indicators>.

EUROPEAN COMMISSION. **A sustainable bioeconomy for Europe:** Strengthening the connection between economy, society and the environment. 2018.

FALCONE, P. M.; TANI, A.; TARTIU, V. E.; IMBRIANI, C. Towards a sustainable forest-based bioeconomy in Italy: Findings from a SWOT analysis. **Forest Policy and Economics**, v. 110, p. 101910, 2020. https://doi.org/10.1016/j.forpol.2019.04.014

FERREIRA, A. F. **Biorefinery concept**. In: (Ed.). Biorefineries: Springer, 2017. p. 1-20. https://doi.org/10.1007/978-3-319-48288-0_1

GATTO, F.; RE, I. Circular Bioeconomy Business Models to Overcome the Valley of Death. A Systematic Statistical Analysis of Studies and Projects in Emerging Bio-Based Technologies and Trends Linked to the SME Instrument Support. **Sustainability**, v. 13, n. 4, 2021. https://doi.org/10.3390/su13041899

GEISSDOERFER, M.; Savaget, P.; Bocken, N. M. P.; Hultink, E. J. The Circular Economy - A new sustainability paradigm? **Journal of Cleaner Production**, v. 143, p. 757-768, 2017. https://doi.org/10.1016/j.jclepro.2016.12.048

GOSWAMI, R. K.; MEHARIYA, S.; VERMA, P.; LAVECCHIA, R.; ZUORRO, A. Microalgae-based biorefineries for sustainable resource recovery from wastewater.

Journal of Water Process Engineering, v. 40, p. 101747, 2021. https://doi.org/10.1016/j.jwpe.2020.101747

GOTTINGER, A.; LADU, L.; QUITZOW, R. Studying the transition towards a circular bioeconomy—a systematic literature review on transition studies and existing barriers. **Sustainability**, v. 12, n. 21, p. 1-27, 2020. https://doi.org/10.3390/su12218990

GOVINDAN, K.; MURUGESAN, P. Selection of third-party reverse logistics provider using fuzzy extent analysis. **Benchmarking: An International Journal**, v. 18, n. 1, p. 149–167, 2011. https://doi.org/10.1108/14635771111109869

GRAEDEL, T.; ALLENBY, B. **Industrial Ecology**. Prentice Hall. Englewood Cliffs, NJ, 1995.

GREGG, J. S.; JURGENS, J.; HAPPEL, M. K.; STROM-ANDERSEN, N.; TANNER, A. N.; BOLWIG, S.; KLITKOU, A. Value chain structures that define European cellulosic ethanol production. **Journal of Cleaner Production**, v. 267, p. 122093, 2020. https://doi.org/10.1016/j.jclepro.2020.122093

GREGORIO, V. F.; PIÉ, L.; TERCEÑO, A. A systematic literature review of bio, green and circular economy trends in publications in the field of economics and business management. **Sustainability**, v. 10, n. 11, p. 4232, 2018. https://doi.org/10.3390/su10114232

GRETZKY, W. **Wayne Gretzky Quotes**. [19--?]. Available at: <https://www.brainyquote.com/quotes/wayne_gretzky_378694>. Accessed 19 Nov 2021.

GUMUS, A.T. Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology, **Expert Systems with Applications**, v. 36, n. 2, p. 4067–4074, 2009. https://doi.org/10.1016/j.eswa.2008.03.013

GYALAI-KORPOS, M. et al. **Bioeconomy opportunities in the danube region**. World Sustainability Series: Springer: 99-116 p. 2018. https://doi.org/10.1007/978-3-319-73028-8_6

HADLEY KERSHAW, E.; HARTLEY, S.; MCLEOD, C.; POLSON, P. The Sustainable Path to a Circular Bioeconomy. **Trends in Biotechnology**, 2021. https://doi.org/10.1016/j.tibtech.2020.10.015

HAGMAN, L.; EKLUND, M.; SVENSSON, N. Assessment of By-product Valorisation in a Swedish Wheat-Based Biorefinery. **Waste and Biomass Valorization**, 2019. https://doi.org/10.1007/s12649-019-00667-0

HAGMAN, L.; FEIZ, R. Advancing the Circular Economy Through Organic by-Product Valorisation: A Multi-criteria Assessment of a Wheat-Based Biorefinery. **Waste and Biomass Valorization**, v. 12, p. 6205–6217, 2021. https://doi.org/10.1007/s12649-021-01440-y

HALLOWELL, M. R.; GAMBATESE, J. A. Qualitative research: Application of the Delphi method to CEM research. **Journal of Construction Engineering and Management**, v. 136, n. 1, p. 99-107, 2010. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000137

HANSEN, E. **Responding to the bioeconomy: business model innovation in the forest sector**. In: (Ed.). Environmental impacts of traditional and innovative forest-based bioproducts: Springer, 2016. p. 227-248. https://doi.org/10.1007/978-981-10-0655-5_7

HEYES, G.; SHARMINA, M., MENDOZA, J.M.F., GALLEGO-SCHMID, A., AZAPAGIC, A. Developing and implementing circular economy business models in service-oriented technology companies. **Journal of Cleaner Production**, v. 177, p. 621-632, 2018. https://doi.org/10.1016/j.jclepro.2017.12.168.

IM, K., CHO, H. A systematic approach for developing a new business model using morphological analysis and integrated fuzzy approach. **Expert Systems with Applications**, v. 40, n. 11, p. 4463-4477, 2013. https://doi.org/10.1016/j.eswa.2013.01.042

IMBERT, E. Food waste valorization options: Opportunities from the bioeconomy. **Open Agriculture**, v. 2, n. 1, p. 195-204, 2017. https://doi.org/10.1515/opag-2017-0020

International Energy Agency. **Energy Technology Perspectives 2015**: Mobilising innovation to accelerate climate action. International Energy Agency. 2015. Accessed 13 December 2021. Available at: <https://doi.org/10.1787/energy_tech-2015-en>.

IOANNIDOU, S. M.; PATERAKI, C.; LADAKIS, D.; PAPAPOSTOLOU, H.; Tsakona, M.; Vlysidis, A.; Kookos, I. K.; Koutinas, A. Sustainable production of bio-based chemicals and polymers via integrated biomass refining and bioprocessing in a circular bioeconomy context. Bioresource Technology, 307, p. 123093, 2020. https://doi.org/10.1016/j.biortech.2020.123093

IPBES. **Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany, 2019.

IPCC. **Summary for Policymakers**. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. 2020.

ISO (International Organisation for Standardisation). **Environmental management — Life cycle assessment — Principles and framework**. ISO, 2006a.

ISO (International Organisation for Standardisation). **Environmental management — Life cycle assessment — Requirements and guidelines**. ISO, 2006b.

JAIN, A.; SARSAIYA, S.; AWASTHI, M. K.; SINGH, R.; RAJPUT, R.; MISHRA, U. C.; CHEN, J. SHI, J. (2022). Bioenergy and bio-products from bio-waste and its associated modern circular economy: Current research trends, challenges, and future outlooks. **Fuel**, v. 307, p. 121859. https://doi.org/10.1016/j.fuel.2021.121859

JANSSEN, K. L.; STEL, F. Orchestrating partnerships in a circular economy – a working method for SMEs. **Proceedings…** XXVIII ISPIM Innovation Conference – Composing the Innovation Symphony, Austria, 18-21 June, 2017.

JARRE, M.; PETIT-BOIX, A.; PRIEFER, C.; MEYER, R.; LEIPOLD, S. Transforming the bio-based sector towards a circular economy - What can we learn from wood cascading? **Forest Policy and Economics**, v. 110, p. 101872, 2020. https://doi.org/10.1016/j.forpol.2019.01.017

JESUS, G. M. K.; JUGEND, D.; PAES, L. A. B.; SIQUEIRA, R. M.; LEANDRIN, M. A. Barriers to the adoption of the circular economy in the Brazilian sugarcane ethanol sector. **Clean Technologies and Environmental Policy**, 2021. https://doi.org/10.1007/s10098-021-02129-5

JIANG, A.; FOING, B. H.; SCHLACHT, I. L.; YAO, X.; CHEUNG, V.; RHODES, P. A. Colour schemes to reduce stress response in the hygiene area of a space station: A Delphi study. **Applied Ergonomics**, v. 98, p. 103573. 2022. https://doi.org/10.1016/j.apergo.2021.103573

JOHNSON, C.; RUIZ SIERRA, A.; DETTMER, J.; SIDIROPOULOU, K.; Zicmane, E.; Canalis, A.; Llorente, P.; Paiano, P.; Mengal, P.; Puzzolo, V. The Bio-Based Industries Joint Undertaking as a catalyst for a green transition in Europe under the European Green Deal. **EFB Bioeconomy Journal**, v. 1, p. 100014, 2021. https://doi.org/10.1016/j.bioeco.2021.100014

JOYCE, A.; PAQUIN, R. L. The triple layered business model canvas: a tool to design more sustainable business models. **Journal of Cleaner Production**, v. 135, p. 1474-1486, 2016. https://doi.org/10.1016/j.jclepro.2016.06.067

KANG, X.; LIN, R.; O’SHEA, R.; DENG, C.; LI, L.; SUN, Y.; MURPHY, J. D. A perspective on decarbonizing whiskey using renewable gaseous biofuel in a circular bioeconomy process. **Journal of Cleaner Production**, 255, p. 120211, 2020. https://doi.org/10.1016/j.jclepro.2020.120211

KAPOOR, R.; GHOSH, P.; KUMAR, M.; SENGUPTA, S.; GUPTA, A.; KUMAR, S. S.; VIJAY, V.; KUMAR, V.; VIJAY, V. K.; PANT, D. Valorization of agricultural waste for biogas based circular economy in India: A research outlook. **Bioresource Technology**, 304, p. 123036, 2020. https://doi.org/10.1016/j.biortech.2020.123036

KARDUNG, M.; CINGIZ, K.; COSTENOBLE, O.; DELAHAYE, R. et al. Development of the circular bioeconomy: Drivers and indicators. **Sustainability**, 13, n. 1, p. 1-24, 2021. https://doi.org/10.3390/su13010413

KASZYCKI, P.; GŁODNIOK, M.; PETRYSZAK, P. Towards a bio-based circular economy in organic waste management and wastewater treatment – The Polish perspective. **New Biotechnology**, 61, p. 80-89, 2021. //doi.org/10.1016/j.nbt.2020.11.005

KAYA, S. K.; AYCIN, E. An integrated interval type 2 fuzzy AHP and COPRAS-G methodologies for supplier selection in the era of Industry 4.0. **Neural Computing**

and Applications, v. 33, p. 10515–10535, 2021. https://doi.org/10.1007/s00521-021-05809-x

KHAIRI, R.; FITRI, S. G.; RUSTAM, Z.; PANDELAKI, J. Fuzzy C-Means Clustering with Minkowski and Euclidean Distance for Cerebral Infarction Classification. **Journal of Physics: Conference Series**, v. 1752, n. 1, p. 012033, 2021. https://doi.org/10.1088/1742-6596/1752/1/012033

KHOSHNEVISAN, B.; DUAN, N.; TSAPEKOS, P.; AWASTHI, M. K. et al. A critical review on livestock manure biorefinery technologies: Sustainability, challenges, and future perspectives. **Renewable & Sustainable Energy Reviews**, v. 135, p. 110033, 2021. https://doi.org/10.1016/j.rser.2020.110033

KIEU, P. T.; NGUYEN, V. T.; NGUYEN, V. T.; HO, T. P. A Spherical Fuzzy Analytic Hierarchy Process (SF-AHP) and Combined Compromise Solution (CoCoSo) Algorithm in Distribution Center Location Selection: A Case Study in Agricultural Supply Chain. **Axioms**, v. 10, n. 2, p. 53, 2021. https://doi.org/10.3390/axioms10020053

KIT LEONG, Y.; CHEW, K. W.; CHEN, W.-H.; CHANG, J.-S. et al. Reuniting the Biogeochemistry of Algae for a Low-Carbon Circular Bioeconomy. **Trends in Plant Science**, 2021. https://doi.org/10.1016/j.tplants.2020.12.010

KLEINSCHMIT, D.; LINDSTAD, B. H.; THORSEN, B. J.; TOPPINEN, A.; ROOS, A.; BAARDSEN, S. Shades of green: a social scientific view on bioeconomy in the forest sector. **Scandinavian journal of forest research**, v. 29, n. 4, p. 402-410, 2014. https://doi.org/10.1080/02827581.2014.921722

KLITKOU, A.; FEVOLDEN, M.; CAPASSO, M. **From waste to value:** Valorisation pathways for organic waste streams in circular bioeconomies. Taylor and Francis, 2019. 1-306. https://doi.org/10.4324/9780429460289

KOKKINOS, K.; KARAYANNIS, V.; MOUSTAKAS, K. Circular bio-economy via energy transition supported by Fuzzy Cognitive Map modeling towards sustainable low-carbon environment. **Science of The Total Environment**, v. 721, p. 137754, 2020. https://doi.org/10.1016/j.scitotenv.2020.137754

KONWAR, L. J. et al. Sidestreams from bioenergy and biorefinery complexes as a resource for circular bioeconomy. In: (Ed.). **Waste Biorefinery**: Elsevier, 2018. p. 85-125. https://doi.org/10.1016/B978-0-444-63992-9.00003-3

KOZLOWSKI, A.; SEARCY, C.; BARDECKI, M. The reDesign canvas: fashion design as a tool for sustainability. **Journal of Cleaner Production**, v. 183, p. 194-207, 2018. https://doi.org/10.1016/j.jclepro.2018.02.014

KUMAR, B.; VERMA, P. Biomass-based biorefineries: An important architype towards a circular economy. **Fuel**, 288, p. 119622, 2021. https://doi.org/10.1016/j.fuel.2020.119622

KWAN, T. H. et al. Valorisation of food and beverage waste via saccharification for sugars recovery. **Bioresource Technology**, v. 255, p. 67-75, 2018. https://doi.org/10.1016/j.biortech.2018.01.077

LADU, L.; IMBERT, E.; QUITZOW, R.; MORONE, P. The role of the policy mix in the transition toward a circular forest bioeconomy. **Forest Policy and Economics**, 110, p. 101937, 2020. https://doi.org/10.1016/j.forpol.2019.05.023

LANGE, L.; CONNOR, K. O.; ARASON, S.; BUNDGÅRD-JØRGENSEN, U. et al. Developing a Sustainable and Circular Bio-Based Economy in EU: By Partnering Across Sectors, Upscaling and Using New Knowledge Faster, and For the Benefit of Climate, Environment & Biodiversity, and People & Business. **Frontiers in Bioengineering and Biotechnology**, 8, 2021. https://doi.org/10.3389/fbioe.2020.619066

LANGSDORF, S. **EU Energy Policy: from the ECSC to the Energy Roadmap 2050**. Brussels: Green European Foundation. Accessed 13 December 2021. Available at <http://archive.gef.eu/uploads/uploads/media/History_of_EU_energy_policy.pdf>.

LEE, H., Kim, C., Park, Y. Evaluation and management of new service concepts: an ANP-based portfolio approach. **Computers & Industrial Engineering**, v. 58, n. 4, p. 535–543, 2010. http://dx.doi.org/10.1016/j.cie.2009.11.016

LEIPOLD, S.; PETIT-BOIX, A. The circular economy and the bio-based sector - Perspectives of European and German stakeholders. **Journal of Cleaner Production**, 201, p. 1125-1137, 2018. https://doi.org/10.1016/j.jclepro.2018.08.019

LESAGE-MEESSEN, L. et al. Lavender- and lavandin-distilled straws: an untapped feedstock with great potential for the production of high-added value compounds and fungal enzymes. **Biotechnology for Biofuels**, v. 11, 2018. https://doi.org/10.1186/s13068-018-1218-5

LEWANDOWSKI, M. Designing the business models for circular economy - Towards the conceptual framework. **Sustainability**, v. 8, n. 1, p. 43, 2016. https://doi.org/10.3390/su8010043

LIU, H. M.; QIN, S. Y.; SIROHI, R.; AHLUWALIA, V. et al. Sustainable blueberry waste recycling towards biorefinery strategy and circular bioeconomy: A review. **Bioresource Technology**, v. 332, 2021. https://doi.org/10.1016/j.biortech.2021.125181

LOIZIDES, M. I. et al. Circular bioeconomy in action: Collection and recycling of domestic used cooking oil through a social, reverse logistics system. **Recycling**, v. 4, n. 2, 2019. https://doi.org/10.3390/recycling4020016

LOPES, G. A. **Avaliação do ciclo de vida de dois materiais de isolamento utilizados na construção civil: o poliestireno expandido e o aglomerado de cortiça expandida**. 2010. Dissertação (Mestrado em Engenharia do Ambiente – Ramo de Gestão) – Faculdade de Engenharia de São Carlos, Universidade do Porto. Porto, 107 p. 2010.

LOVINS, A. B.; LOVINS, L. H.; HAWKEN, P. **A road map for natural capitalism**. 1999.

LYBÆK, R.; KJÆR, T. Biogas Technology as an “Engine” for Facilitating Circular Bio-Economy in Denmark—The Case of Lolland & Falster Municipalities Within Region Zealand. **Frontiers in Energy Research**, v. 9, 2021. https://doi.org/10.3389/fenrg.2021.695685

LYBÆK, R.; KJÆR, T. How Circular Bio-Economy Can Be Adopted within the Agro-Industry in Denmark by Cascading and Coupling Biomass Residues. **GMSARN International Journal**, 16, n. 1, p. 93-98, 2022.

LYLE, J. T. **Regenerative design for sustainable development**. John Wiley & Sons, 1996.

MADADIAN, E.; HAELSSIG, J. B.; MOHEBBI, M.; PEGG, M. From biorefinery landfills towards a sustainable circular bioeconomy: A techno-economic and environmental analysis in Atlantic Canada. **Journal of Cleaner Production**, v. 296, p. 126590, 2021. https://doi.org/10.1016/j.jclepro.2021.126590

MAINA, S.; KACHRIMANIDOU, V.; KOUTINAS, A. A roadmap towards a circular and sustainable bioeconomy through waste valorization. **Current Opinion in Green and Sustainable Chemistry**, v. 8, p. 18-23, 2017. https://doi.org/10.1016/j.cogsc.2017.07.007

MAK, T. M. W.; XIONG, X.; TSANG, D. C. W.; YU, I. K. M. et al. Sustainable food waste management towards circular bioeconomy: Policy review, limitations and opportunities. **Bioresource Technology**, v. 297, p. 122497, 2020. https://doi.org/10.1016/j.biortech.2019.122497

MARCINEK, P.; SMOL, M. Bioeconomy as one of the key areas of implementing a circular economy (CE) in Poland. **Environmental Research, Engineering and Management**, 76, n. 4, p. 20-31, 2020. https://doi.org/10.5755/j01.erem.76.4.27536

MCDONOUGH, W.; BRAUNGART, M. **Remaking the way we make things:** Cradle to cradle. New York: North Point Press. ISBN 1224942886, 2002.

MEHTA, N.; SHAH, K. J.; LIN, Y. I.; SUN, Y. et al. Advances in circular bioeconomy technologies: From agricultural wastewater to value-added resources. **Environments**, v. 8, n. 3, p. 1-23, 2021. https://doi.org/10.3390/environments8030020

MENDES, N. C. **Métodos e modelos de caracterização para avaliação de impacto do ciclo de vida: análise e subsídios para a aplicação no Brasil**. Dissertação (Mestrado em Engenharia de Produção) – Escola de Engenharia de São Carlos, Universidade de São Paulo. São Carlos, 149 p. 2013.

MENGAL, P. et al. Bio-based Industries Joint Undertaking: The catalyst for sustainable bio-based economic growth in Europe. **New Biotechnology**, v. 40, p. 31-39, 2018. https://doi.org/10.1016/j.nbt.2017.06.002

MENON, A.; LYNG, J. G. Circular bioeconomy solutions: driving anaerobic digestion of waste streams towards production of high value medium chain fatty acids. **Reviews in Environmental Science and Biotechnology**, v. 20, n. 1, p. 189-208, 2021. https://doi.org/10.1007/s11157-020-09559-5

MIKIELEWICZ, D.; DĄBROWSKI, P.; BOCHNIAK, R.; GOŁĄBEK, A. Current status, barriers and development perspectives for circular bioeconomy in Polish south Baltic area. Sustainability, v. 12, n. 21, p. 1-15, 2020. https://doi.org/10.3390/su12219155

MODESTO, H. R.; LEMOS, S. G., DOS SANTOS, M. S., KOMATSU, J. S., GONÇALVES, M., CARVALHO, W. A., CARRILHO, E. N. V. M.; Labuto, G. Activated carbon production from industrial yeast residue to boost up circular bioeconomy. **Environmental Science and Pollution Research**, v. 28, p. 24694–24705, 2021. https://doi.org/10.1007/s11356-020-10458-z

MOHAN, S. V. et al. Waste Biorefinery: A New Paradigm for a Sustainable Bioelectro Economy. **Trends in Biotechnology**, v. 34, n. 11, p. 852-855, 2016. https://doi.org/10.1007/s11356-020-10458-z

MOHAN, S. V. et al. Waste derived bioeconomy in India: A perspective. **New Biotechnology**, v. 40, p. 60-69, 2018. https://doi.org/10.1016/j.nbt.2017.06.006

MOKTADIR, M.A.; ALI, S.M.; PAUL, S.K.; SHUKLA, N. Barriers to big data analytics in manufacturing supply chains: a case study from Bangladesh. **Computers & Industrial Engineering**, v. 128, p. 1063–1075, 2019. https://doi.org/10.1016/j.cie.2018.04.013

MOREIRA, J. B.; SANTOS, T. D.; DUARTE, J. H.; BEZERRA, P. Q. M. et al. Role of microalgae in circular bioeconomy: from waste treatment to biofuel production. **Clean Technologies and Environmental Policy**, 2021. https://doi.org/10.1007/s10098-021-02149-1

MORONE, P.; IMBERT, E. Food waste and social acceptance of a circular bioeconomy: the role of stakeholders. **Current Opinion in Green and Sustainable Chemistry**, 23, p. 55-60, 2020. https://doi.org/10.1016/j.cogsc.2020.02.006

MPOFU, A. B.; OYEKOLA, O. O.; WELZ, P. J. Anaerobic treatment of tannery wastewater in the context of a circular bioeconomy for developing countries. **Journal of Cleaner Production**, v. 296, p. 126490, 2021. https://doi.org/10.1016/j.jclepro.2021.126490

MUSCAT, A.; DE OLDE, E. M.; RIPOLL-BOSCH, R.; VAN ZANTEN, H. H. E. et al. Principles, drivers and opportunities of a circular bioeconomy. **Nature Food**, 2021. https://doi.org/10.1038/s43016-021-00340-7

MUSTALAHTI, I. The responsive bioeconomy: The need for inclusion of citizens and environmental capability in the forest based bioeconomy. **Journal of Cleaner Production**, v. 172, p. 3781-3790, 2018. https://doi.org/10.1016/j.jclepro.2017.06.132

NAGARAJAN, D.; LEE, D. J.; CHEN, C. Y.; CHANG, J. S. Resource recovery from wastewaters using microalgae-based approaches: A circular bioeconomy perspective. **Bioresource Technology**, v. 302, 2020. https://doi.org/10.1016/j.biortech.2020.122817

NÄYHÄ, A. Backcasting for desirable futures in Finnish forest-based firms. **Foresight**, v. 23, n. 1, p. 50-72, 2021. https://doi.org/10.1108/fs-01-2020-0005

NÄYHÄ, A. Finnish forest-based companies in transition to the circular bioeconomy - drivers, organizational resources and innovations. **Forest Policy and Economics**, v. 110, 2020. https://doi.org/10.1016/j.forpol.2019.05.022

NÄYHÄ, A. Transition in the Finnish forest-based sector: Company perspectives on the bioeconomy, circular economy and sustainability. **Journal of Cleaner Production**, v. 209, p. 1294-1306, 2019. https://doi.org/10.1016/j.jclepro.2018.10.260

NÄYHÄ, A., PESONEN, H. L. Strategic change in the forest industry towards the biorefining business. **Technological Forecasting and Social Change**, v. 81, p. 259-271, 2014. http://dx.doi.org/10.1016/j.techfore.2013.04.014

NÄYHÄ, A.; PESONEN, H.-L. Diffusion of forest biorefineries in Scandinavia and North America. **Technological Forecasting and Social Change**, v. 79, n. 6, p. 1111-1120, 2012. https://doi.org/10.1016/j.techfore.2012.01.006

NEGI, S.; HU, A.; KUMAR, S. 24 - Circular Bioeconomy: Countries' Case Studies. In: PANDEY, A.;TYAGI, R. D., et al (Ed.). Biomass, Biofuels, Biochemicals: Elsevier, p. 721-748, 2021. https://doi.org/10.1016/B978-0-12-821878-5.00008-8

NUSSHOLZ, J. L. A circular business model mapping tool for creating value from prolonged product lifetime and closed material loops. **Journal of Cleaner Production**, v. 197, p. 185-194, 2018. https://doi.org/10.1016/j.jclepro.2018.06.112

ODEGARD, I.; CROEZEN, H.; BERGSMA, G. **Cascading of Biomass:** 13 Solutions for a Sustainable Bio-based Economy: Making Better Choices for Use of Biomass Residues, By-products and Wastes. CE Delft, 2012.

OSTERWALDER, A.; PIGNEUR, Y. **Business model generation:** a handbook for visionaries, game changers, and challengers. John Wiley & Sons, 2010.

OSTERWALDER, A.; PIGNEUR, Y.; TUCCI, C. L. Clarifying business models: Origins, present, and future of the concept. **Communications of the association for Information Systems**, v. 16, n. 1, p. 1, 2005. https://doi.org/10.17705/1CAIS.01601

OVERTURF, E.; RAVASIO, N.; ZACCHERIA, F.; TONIN, C. et al. Towards a more sustainable circular bioeconomy. Innovative approaches to rice residue valorization: The RiceRes case study. **Bioresource Technology Reports**, v. 11, p. 100427, 2020. https://doi.org/10.17705/1CAIS.01601

PAES, L. A. B.; BEZERRA, B. S.; DEUS, R. M.; JUGEND, D. et al. Organic solid waste management in a circular economy perspective - A systematic review and SWOT analysis. **Journal of Cleaner Production**, v. 239, 2019. https://doi.org/10.1016/j.jclepro.2019.118086

PAGLIARO, M. Waste-to-wealth: The economic reasons for replacing waste-to-energy with the circular economy of municipal solid waste. **Visions for Sustainability**, n. 13, p. 59-65, 2020. https://doi.org/10.13135/2384-8677/4421

PALAHÍ, M., PANTSAR, M., COSTANZA, R., KUBISZEWSKI, I. et al. **Investing in Nature as the true engine of our economy: A 10-point Action Plan for a Circular Bioeconomy of Wellbeing**. Knowledge to Action 02, European Forest Institute, 2020. https://doi.org/10.36333/k2a02

PAN, S.-Y. et al. Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system: a review. **Journal of Cleaner Production**, v. 108, p. 409-421, 2015. https://doi.org/10.1016/j.isci.2021.102704

PAREDES-SANCHEZ, J. P. et al. Evolution and perspectives of the bioenergy applications in Spain. **Journal of Cleaner Production**, v. 213, p. 553-568, 2019. https://doi.org/10.1016/j.jclepro.2018.12.112

PAULI, G. A. **The blue economy:** 10 years, 100 innovations, 100 million jobs. Paradigm publications, 2010.

PEARCE, D. W.; TURNER, R. K. **Economics of natural resources and the environment**. JHU Press, 1990.

PETIT-BOIX, A.; LEIPOLD, S. Circular economy in cities: Reviewing how environmental research aligns with local practices. **Journal of Cleaner Production**, v. 195, p. 1270-1281, 2018. https://doi.org/10.1016/j.jclepro.2018.05.281

PIERONI, M. P.; MCALOONE, T. C.; BORGIANNI, Y.; MACCIONI, L.; PIGOSSO, D. C. An expert system for circular economy business modelling: Advising manufacturing companies in decoupling value creation from resource consumption. **Sustainable Production and Consumption**, v. 27, p. 534-550, 2021. https://doi.org/10.1016/j.spc.2021.01.023

PIERONI, M. D. P.; PIGOSSO, D. C. A.; MCALOONE, T. C. Sustainable Qualifying Criteria for Designing Circular Business Models. **Procedia CIRP**, v. 69, p. 799-804, 2018. https://doi.org/10.1016/j.procir.2017.11.014

PRASAD, M. N. V. **Bioremediation and bioeconomy**. Elsevier, 2015. ISBN 0128028726.

PUYOL, D. et al. Resource Recovery from Wastewater by Biological Technologies: Opportunities, Challenges, and Prospects. **Frontiers in Microbiology**, v. 7, 2017. https://doi.org/10.3389/fmicb.2016.02106

QIN, S. Y.; GIRI, B. S.; PATEL, A. K.; SAR, T. et al. Resource recovery and biorefinery potential of apple orchard waste in the circular bioeconomy. **Bioresource Technology**, v. 321, 2021. https://doi.org/10.1016/j.biortech.2020.124496

RASMUSSEN, B. **Business Models and the Theory of the Firm**. 2007.

RAUGEI, M.; PELUSO, A.; LECCISI, E.; FTHENAKIS, V. Life-Cycle Carbon Emissions and Energy Return on Investment for 80% Domestic Renewable Electricity with Battery Storage in California (USA). **Energies**, v. 13, n. 15, p. 3934, 2020. https://doi.org/10.3390/en13153934

REIM, W.; PARIDA, V.; SJODIN, D. R. Circular Business Models for the Bio-Economy: A Review and New Directions for Future Research. **Sustainability**, v. 11, n. 9, 2019. https://doi.org/10.3390/su11092558

REIM, W.; SJÖDIN, D.; PARIDA, V.; ROVA, U.; CHRISTAKOPOULOS, P. Bio-economy based business models for the forest sector–A systematic literature review. In: International scientific conference RURAL DEVELOPMENT 2017, 2017, Kaunas. **Proceedings …** Kaunas: Aleksandras Stulginskis University, 2007. p. 775-780.

REKLEITIS, G.; HARALAMBOUS, K. J.; LOIZIDOU, M.; ARAVOSSIS, K. Utilization of agricultural and livestock waste in anaerobic digestion (A.D): Applying the biorefinery concept in a circular economy. **Energies**, 13, n. 17, 2020. https://doi.org/10.3390/en13174428

RICHARDSON, J. The business model: an integrative framework for strategy execution. **Strategic change**, v. 17, n. 5-6, p. 133-144, 2008. http://dx.doi.org/10.2139/ssrn.932998

RODIAS, E.; AIVAZIDOU, E.; ACHILLAS, C.; AIDONIS, D. et al. Water-Energy-Nutrients Synergies in the Agrifood Sector: A Circular Economy Framework. **Energies**, 14, n. 1, 2021. https://doi.org/10.3390/en14010159

ROE, S.; STRECK, C.; OBERSTEINER, M.; Frank, S. et al. Contribution of the land sector to a 1.5 °C world. Nature Climate Change, n. 9, p. 817-828, 2019. https://doi.org/10.1038/s41558-019-0591-9

ROOS, A.; STENDAHL, M. **The emerging bio-economy and the forest sector**. In: (Ed.). Forests, Business and Sustainability: Routledge, 2015. p. 193-215.

ROSENBAUM, R.; BACHMANN, T.; GOLD, L.; HUIJBREGTS, M.; JOLLIET, O.; JURASKE, R.; KOEHLER, A.; LARSEN, H. F.; MACLEOD, M; MARGNI, M.; MCKONE, T. E.; PAYET, J.; SCHUHMACHER, M.; VAN DE MEENT, D.; HAUSCHILD, M. USEtox–The UNEP-SETAC toxicity model: Recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. **International Journal of Life Cycle Assessment**, v. 13, p. 532-546, 2008. http://doi.org/10.1007/s11367-008-0038-4

RYABCHENKO, O.; GOLUB, G.; TURČEKOVÁ, N.; ADAMIČKOVÁ, I. et al. Sustainable business modeling of circular agriculture production: Case study of circular bioeconomy. **Journal of Security and Sustainability Issues**, v. 7, n. 2, p. 301-309, 2017. http://doi.org/10.9770/jssi.2017.7.2(10)

SAATY, T.L. **The Analytic Hierarchy Process**. McGraw-Hill, New York, 1980.

SADHUKHAN, J.; DUGMORE, T. I. J.; MATHARU, A.; MARTINEZ-HERNANDEZ, E. et al. Perspectives on "game changer" global challenges for sustainable 21st century: Plant-based diet, unavoidable food waste biorefining, and circular economy. **Sustainability**, v. 12, n. 5, 2020. http://doi.org/10.3390/su12051976

SALVADOR, R. et al. Circular business models: Current aspects that influence implementation and unaddressed subjects. **Journal of Cleaner Production**, v. 250, p. 119555, 2020. https://doi.org/10.1016/j.jclepro.2019.119555

SALVADOR, R.; BARROS, M. V.; FREIRE, F.; HALOG, A. et al. Circular economy strategies on business modelling: Identifying the greatest influences. **Journal of Cleaner Production**, n. 299, p. 126918, 2021a. https://doi.org/10.1016/j.jclepro.2021.126918

SALVADOR, R.; PEREIRA, R. B.; SALES, G. F.; OLIVEIRA, V. C. V. et al. Current panorama, practice gaps, and recommendations to accelerate the transition to a circular bioeconomy in Latin America and the Caribbean. **Circular Economy and Sustainability**, 2021b. *In Press*.

SALVADOR, R.; PUGLIERI, F. N.; HALOG, A.; ANDRADE, F. G. D. et al. Key aspects for designing business models for a circular bioeconomy. **Journal of Cleaner Production**, v. 278, p. 124341, 2021c. https://doi.org/10.1016/j.jclepro.2020.124341

SANDVOLD, H. N.; GREGG, J. S.; OLSEN, D. S. **8 New pathways for organic waste in land-based farming of salmon**. From Waste to Value: Valorisation Pathways for Organic Waste Streams in Circular Bioeconomies, p. 145, 2019. https://doi.org/10.4324/9780429460289-8

SANTAGATA, R.; RIPA, M.; GENOVESE, A.; ULGIATI, S. Food waste recovery pathways: Challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment. **Journal of Cleaner Production**, v. 286, p. 125490, 2021. https://doi.org/10.1016/j.jclepro.2020.125490

SANTANA, D. A. R.; SCATOLINO, M. V.; LIMA, M. D. R.; DE OLIVEIRA BARROS JUNIOR, U. et al. Pelletizing of lignocellulosic wastes as an environmentally friendly solution for the energy supply: insights on the properties of pellets from Brazilian biomasses. **Environmental Science and Pollution Research**, v. 28, n. 9, p. 11598-11617, 2021. https://doi.org/10.1007/s11356-020-11401-y

SARMA, S.; SHARMA, S.; RUDAKIYA, D.; UPADHYAY, J. et al. Valorization of microalgae biomass into bioproducts promoting circular bioeconomy: a holistic approach of bioremediation and biorefinery. 3 Biotech, 11, n. 8, 2021. https://doi.org/10.1007/s13205-021-02911-8

SCHULTE, U. G. New business models for a radical change in resource efficiency. **Environmental Innovation and Societal Transitions**, v. 9, p. 43-47, 2013. https://doi.org/10.1016/j.eist.2013.09.006

SECME, N.Y.; BAYRAKDAROGLU, A.; KAHRAMAN, C. Fuzzy Performance Evaluation in Turkish Banking Sector Using Analytic Hierarchy Process and TOPSIS. **Expert Systems with Applications**, v. 36, n. 9, p. 11699–11709, 2009. https://doi.org/10.1016/j.eswa.2009.03.013

SEFEEDPARI, P.; PUDELKO, R.; JEDREJEK, A.; KOZAK, M. et al. To What Extent Is Manure Produced, Distributed, and Potentially Available for Bioenergy? A Step toward Stimulating Circular Bio-Economy in Poland. **Energies**, 13, n. 23, 2020. https://doi.org/10.3390/en13236266

SHARMA, P.; GAUR, V. K.; SIROHI, R.; VARJANI, S. et al. Sustainable processing of food waste for production of bio-based products for circular bioeconomy. **Bioresource Technology**, v. 325, p. 124684, 2021. https://doi.org/10.1016/j.biortech.2021.124684

SHERWOOD, J. The significance of biomass in a circular economy. **Bioresource Technology**, v. 300, p. 122755, 2020. https://doi.org/10.1016/j.biortech.2020.122755

SHIRSATH, A. P.; HENCHION, M. M. Bovine and ovine meat co-products valorisation opportunities: A systematic literature review. **Trends in Food Science & Technology**, 2021. https://doi.org/10.1016/j.tifs.2021.08.015

SOLIS, C. A.; MAYOL, A. P.; SAN JUAN, J. G.; UBANDO, A. T., CULABA, A. B. Multi-objective optimal synthesis of algal biorefineries toward a sustainable circular bioeconomy. **Proceedings**… In IOP Conference Series: Earth and Environmental Science, v. 463, n. 1, p. 012051, 2020. https://doi.org/10.1088/1755-1315/463/1/012051

SONNENBERG, A.; BAARS, J.; HENDRICKX, P. **IEA Bioenergy Task 42 Biorefinery. Avantium, Biomass Research and Wageningen University and Research Centre**: Wageningen, The Netherlands, 2007.

STAHEL, W. **The performance economy**. Springer, 2010. ISBN 0230274900.

STEFFEN, W. et al. Planetary boundaries: Guiding human development on a changing planet. **Science**, v. 347, n. 6223, p. 1259855, 2015. https://doi.org/10.1126/science.1259855

STEGMANN, P.; LONDO, M.; JUNGINGER, M. The circular bioeconomy: Its elements and role in European bioeconomy clusters. Resources, Conservation & Recycling: X, v. 6, p. 100029, 2020. https://doi.org/10.1016/j.rcrx.2019.100029

TAFFURI, A.; SCIULLO, A.; DIEMER, A.; NEDELCIU, C. E. Integrating circular bioeconomy and urban dynamics to define an innovative management of bio-waste: The study case of turin. Sustainability, v. 13, n. 11, 2021. https://doi.org/10.3390/su13116224

TEECE, D. J. Business models, business strategy and innovation. **Long range planning**, v. 43, n. 2-3, p. 172-194, 2010. https://doi.org/10.1016/j.lrp.2009.07.003

TEMMES, A.; PECK, P. Do forest biorefineries fit with working principles of a circular bioeconomy? A case of Finnish and Swedish initiatives. **Forest Policy and Economics**, v. 110, p. 101896, 2020. https://doi.org/10.1016/j.forpol.2019.03.013

TOPPINEN, A. et al. The European pulp and paper industry in transition to a bio-economy: A Delphi study. **Futures**, v. 88, p. 1-14, 2017. https://doi.org/10.1016/j.futures.2017.02.002

TRØMBORG, E. et al. Economic sustainability for wood pellets production – A comparative study between Finland, Germany, Norway, Sweden and the US. **Biomass and bioenergy**, v. 57, p. 68-77, 2013. https://doi.org/10.1016/j.biombioe.2013.01.030

TSAI, W. T.; LIN, Y. Q. Analysis of promotion policies for the valorization of food waste from industrial sources in Taiwan. **Fermentation**, v. 7, n. 2, 2021. https://doi.org/10.3390/fermentation7020051

TSEGAYE, B.; JAISWAL, S.; JAISWAL, A. K. Food waste biorefinery: Pathway towards circular bioeconomy. **Foods**, v. 10, n. 6, 2021. https://doi.org/10.3390/foods10061174

TUKKER, A. Product services for a resource-efficient and circular economy – a review. **Journal of Cleaner Production**, v. 97, p. 76-91, 2015. https://doi.org/10.1016/j.jclepro.2013.11.049

UBANDO, A. T.; FELIX, C. B.; CHEN, W.-H. Biorefineries in circular bioeconomy: A comprehensive review. **Bioresource Technology**, v. 299, p. 122585, 2019. https://doi.org/10.1016/j.biortech.2019.122585

UGAYA, C. M. L.; DE ALMEIDA NETO, J. A.; DE FIGUEIREDO, M. C. B. **Recomendações de modelos de Avaliação de Impacto do Ciclo de Vida para o contexto brasileiro**. Brasília: Instituto Brasileiro de Informação em Ciência e Tecnologia, Ibict, 2019.

UNEP (United Nations Environment Programme). **Eco-i Manual:** Eco-innovation implementation process. Environment Economy Division, 2017.

URBINATI, A.; CHIARONI, D.; CHIESA, V. Towards a new taxonomy of circular economy business models. **Journal of Cleaner Production**, v. 168, p. 487-498, 2017. https://doi.org/10.1016/j.jclepro.2017.09.047

USMANI, Z.; SHARMA, M.; AWASTHI, A. K.; LUKK, T. et al. Lignocellulosic biorefineries: The current state of challenges and strategies for efficient commercialization. **Renewable and Sustainable Energy Reviews**, v. 148, p. 111258, 2021. https://doi.org/10.1016/j.rser.2021.111258

VANHAMÄKI, S.; SCHNEIDER, G.; MANSKINEN, K. Perspectives on Sustainable Bioeconomy in the Baltic Sea Region. **International Journal of Economics and Management Engineering**, v. 13, n. 4, p. 470-475, 2019. https://doi.org/10.5281/zenodo.2643997

VEA, E. B.; ROMEO, D.; THOMSEN, M. Biowaste Valorisation in a Future Circular Bioeconomy. **Procedia CIRP**, v. 69, p. 591-596, 2018. https://doi.org/10.1016/j.procir.2017.11.062

VERBURG, G. **Government vision on the bio-based economy in the energy transition** [*Overheidsvisie op de bio-based economy in de energietransitie*]. 2007. Available at: https://refman.energytransitionmodel.com/publications/304/download. Accessed 12 Nov 2021.

VERKERK, P. J.; COSTANZA, R.; HETEMÄKI, L.; KUBISZEWSKI, I. et al. Climate-Smart Forestry: the missing link. **Forest Policy and Economics**, v. 115, p. 102164, 2020. https://doi.org/10.1016/j.forpol.2020.102164

WBCSD (World Business Council for Sustainable Development). **CEO Guide to the Circular Economy**. WBCSD: Geneva, Switzerland, 2017.

WBCSD (World Business Council for Sustainable Development). **CEO Guide to the Circular Bioeconomy**. WBCSD: Geneva, Switzerland, 2019.

WESSELING, J. H.; LECHTENBÖHMER, S.; ÅHMAN, M.; NILSSON, L. J. et al. The transition of energy intensive processing industries towards deep decarbonization: characteristics and implications for future research. **Renewable and Sustainable Energy Reviews**, n. 79, p. 1303-1313, 2017. https://doi.org/10.1016/j.rser.2017.05.156 "

WINKEL, G. **Towards a sustainable European forest-based bioeconomy: Assessment and the way forward**. European Forest Institute (EFI), 2017. ISBN 9525980421.

WIRTZ, B. W. et al. Business models**:** Origin, development and future research perspectives. **Long range planning**, v. 49, n. 1, p. 36-54, 2016. https://doi.org/10.1016/j.lrp.2015.04.001

WUEBBLES, D. J. **Ozone Depletion and Related Topics**: Ozone Depletion Potentials. In Encyclopedia of Atmospheric Sciences: Second Edition (pp. 364-369). Elsevier Inc., 2015. https://doi.org/10.1016/B978-0-12-382225-3.00293-0

YI LEONG, H.; CHANG, C. K.; KHOO, K. S.; CHEW, K. W. et al. Waste biorefinery towards a sustainable circular bioeconomy: a solution to global issues**. Biotechnology for Biofuels**, v. 14, n. 1, 2021. https://doi.org/10.1186/s13068-021-01939-5

ZADEH, L. A. A fuzzy-algorithmic approach to the definition of complex or imprecise concepts. **International Journal of Man-Machine Studies**, v. 8, n. 3, p.249–291, 1976. http://dx.doi.org/10.1016/S0020-7373(76)80001-6.

ZADEH, L. A. Fuzzy sets. **Information and control**, v. 8, n. 3, p. 338-353, 1965.

ZECEVIC, M.; PEZO, L.; BODROZA-SOLAROV, M.; BRLEK, T. et al. A Business Model in Agricultural Production in Serbia, Developing Towards Sustainability. **Ekonomika Poljoprivreda-Economics of Agriculture**, v. 66, n. 2, p. 437-456, 2019.

APPENDIX A - Final Portfolio of Documents from Systematic Literature Review

Table A. 1 - Final portfolio for search string 1

Reference	Title	Type of Publication	Journal/Publisher
Alexandri *et al.* (2020)	Valorising Agro-industrial Wastes within the Circular Bioeconomy Concept: the Case of Defatted Rice Bran with Emphasis on Bioconversion Strategies	Journal Article	Fermentation-Basel
Amit *et al.* (2021)	Food industries wastewater recycling for biodiesel production through microalgal remediation	Journal Article	Sustainability (Switzerland)
Angouria-Tsorochidou *et al.* (2021)	Limits to circular bioeconomy in the transition towards decentralized biowaste management systems	Journal Article	Resources, Conservation and Recycling
Awasthi *et al.* (2019)	A critical review of organic manure biorefinery models toward sustainable circular bioeconomy: Technological challenges, advancements, innovations, and future perspectives	Journal Article	Renewable and Sustainable Energy Reviews
Awasthi *et al.* (2020)	Refining biomass residues for sustainable energy and bio-products: An assessment of technology, its importance, and strategic applications in circular bio-economy	Journal Article	Renewable and Sustainable Energy Reviews
Banu *et al.* (2020a)	Biorefinery of spent coffee grounds waste: Viable pathway towards circular bioeconomy	Journal Article	Bioresource Technology
Banu *et al.* (2020b)	Microalgae based biorefinery promoting circular bioeconomy-techno economic and life-cycle analysis	Journal Article	Bioresource Technology
Barcelos *et al.* (2021)	Circularity of Brazilian silk: Promoting a circular bioeconomy in the production of silk cocoons	Journal Article	Journal of Environmental Management
Barros *et al.* (2020)	Mapping of research lines on circular economy practices in agriculture: From waste to energy	Journal Article	Renewable and Sustainable Energy Reviews
Behera *et al.* (2021)	Integrated microalgal biorefinery for the production and application of biostimulants in circular bioeconomy	Journal Article	Bioresource Technology
Berbel and Posadillo (2018)	Review and analysis of alternatives for the valorisation of agro-industrial olive oil by-products	Journal Article	Sustainability (Switzerland)
Bian *et al.* (2020)	Microbial electrosynthesis from CO_2: Challenges, opportunities and perspectives in the context of circular bioeconomy	Journal Article	Bioresource Technology
Bolwig *et al.* (2019)	Beyond animal feed?: The valorisation of brewers' spent grain	Book Chapter	From Waste to Value: Valorisation Pathways for Organic Waste Streams in Circular Bioeconomies
Bos and Broeze (2020)	Circular bio-based production systems in the context of current biomass and fossil demand	Journal Article	Biofuels, Bioproducts and Biorefining

Reference	Title	Type of Publication	Journal/Publisher
Brandão *et al.* (2021)	Circular bioeconomy strategies: From scientific research to commercially viable products	Journal Article	Journal of Cleaner Production
Bugge *et al.* (2019)	Theoretical perspectives on innovation for waste valorisation in the bioeconomy	Book Chapter	From Waste to Value: Valorisation Pathways for Organic Waste Streams in Circular Bioeconomies
Catone *et al.* (2021)	Bio-products from algae-based biorefinery on wastewater: A review	Journal Article	Journal of Environmental Management
Chandrasekhar et al. (2020)	Waste based hydrogen production for circular bioeconomy: Current status and future directions	Journal Article	Bioresource Technology
Cheng *et al.* (2020)	Incorporating biowaste into circular bioeconomy: A critical review of current trend and scaling up feasibility	Journal Article	Environmental Technology & Innovation
Chowdhary *et al.* (2021)	Current trends and possibilities for exploitation of Grape pomace as a potential source for value addition	Journal Article	Environmental Pollution
Clauser *et al.* (2021)	Biomass waste as sustainable raw material for energy and fuels	Journal Article	Sustainability (Switzerland)
Coppola *et al.* (2021)	Fish Waste: From Problem to Valuable Resource	Journal Article	Marine drugs
Dahal *et al.* (2021)	Biochar: a sustainable solution for solid waste management in agro-processing industries	Journal Article	Biofuels
Dahiya *et al.* (2018)	Food waste biorefinery: Sustainable strategy for circular bioeconomy	Journal Article	Bioresource Technology
D'Amato *et al.* (2020)	Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs	Journal Article	Forest Policy and Economics
DeBoer *et al.* (2020)	Squaring the circle: Refining the competitiveness logic for the circular bioeconomy	Journal Article	Forest Policy and Economics
Donner and Radic (2021)	Innovative circular business models in the olive oil sector for sustainable mediterranean agrifood systems	Journal Article	Sustainability (Switzerland)
Donner and Vries (2021)	How to innovate business models for a circular bio-economy?	Journal Article	Business Strategy and the Environment
Donner and Vries (2021)	How to innovate business models for a circular bio-economy?	Journal Article	Business Strategy and the Environment
Donner *et al.* (2020)	A new circular business model typology for creating value from agro-waste	Journal Article	Science of The Total Environment
Donner *et al.* (2021)	Critical success and risk factors for circular business models valorising agricultural waste and by-products	Journal Article	Resources, Conservation and Recycling
Donner *et al.* (2021)	Critical success and risk factors for circular business models valorising agricultural waste and by-products	Journal Article	Resources Conservation and Recycling

Reference	Title	Type of Publication	Journal/Publisher
Duan *et al.* (2020)	Organic solid waste biorefinery: Sustainable strategy for emerging circular bioeconomy in China	Journal Article	Industrial Crops and Products
Duarte *et al.* (2021)	Enhancing bioenergy recovery from agro-food biowastes as a strategy to promote circular bioeconomy	Journal Article	Journal of Sustainable Development of Energy, Water and Environment Systems
Duque-Acevedo *et al.* (2020a)	The Management of Agricultural Waste Biomass in the Framework of Circular Economy and Bioeconomy: An Opportunity for Greenhouse Agriculture in Southeast Spain	Journal Article	Agronomy-Basel
Duque-Acevedo *et al.* (2020b)	Analysis of the Circular Economic Production Models and Their Approach in Agriculture and Agricultural Waste Biomass Management	Journal Article	International Journal of Environmental Research and Public Health
Egea *et al.* (2018)	An efficient agro-industrial complex in Almería (Spain): Towards an integrated and sustainable bioeconomy model	Journal Article	New Biotechnology
Egelyng *et al.* (2018)	Cascading Norwegian co-streams for bioeconomic transition	Journal Article	Journal of Cleaner Production
Falcone *et al.* (2020)	Towards a sustainable forest-based bioeconomy in Italy: Findings from a SWOT analysis	Journal Article	Forest Policy and Economics
Goswami *et al.* (2021)	Microalgae-based biorefineries for sustainable resource recovery from wastewater	Journal Article	Journal of Water Process Engineering
Gottinger *et al.* (2020)	Studying the transition towards a circular bioeconomy—a systematic literature review on transition studies and existing barriers	Journal Article	Sustainability (Switzerland)
Gregg *et al.* (2020)	Valorization of bio-residuals in the food and forestry sectors in support of a circular bioeconomy: A review	Journal Article	Journal of Cleaner Production
Gyalai-Korpos *et al.* (2018)	Bioeconomy opportunities in the danube region	Book Chapter	Towards a Sustainable Bioeconomy: Principles, Challenges and Perspectives
Hadley Kershaw *et al.* (2021)	The Sustainable Path to a Circular Bioeconomy	Journal Article	Trends in Biotechnology
Hagman and Feiz (2021)	Advancing the Circular Economy Through Organic by-Product Valorisation: A Multi-criteria Assessment of a Wheat-Based Biorefinery	Journal Article	Waste and Biomass Valorization
Hagman *et al.* (2019)	Assessment of By-product Valorisation in a Swedish Wheat-Based Biorefinery	Journal Article	Waste and Biomass Valorization
Imbert (2017)	Food waste valorization options: Opportunities from the bioeconomy	Journal Article	Open Agriculture
Ioannidou *et al.* (2020)	Sustainable production of bio-based chemicals and polymers via integrated biomass refining and bioprocessing in a circular bioeconomy context	Journal Article	Bioresource Technology

Reference	Title	Type of Publication	Journal/Publisher
Jain *et al.* (2022)	Bioenergy and bio-products from bio-waste and its associated modern circular economy: Current research trends, challenges, and future outlooks	Journal Article	Fuel
Jarre *et al.* (2020)	Transforming the bio-based sector towards a circular economy - What can we learn from wood cascading?	Journal Article	Forest Policy and Economics
Jesus *et al.* (2021)	Barriers to the adoption of the circular economy in the Brazilian sugarcane ethanol sector	Journal Article	Clean Technologies and Environmental Policy
Johnson *et al.* (2021)	The Bio-Based Industries Joint Undertaking as a catalyst for a green transition in Europe under the European Green Deal	Journal Article	EFB Bioeconomy Journal
Kang *et al.* (2020)	A perspective on decarbonizing whiskey using renewable gaseous biofuel in a circular bioeconomy process	Journal Article	Journal of Cleaner Production
Kapoor *et al.* (2020)	Valorization of agricultural waste for biogas based circular economy in India: A research outlook	Journal Article	Bioresource Technology
Kardung *et al.* (2021)	Development of the circular bioeconomy: Drivers and indicators	Journal Article	Sustainability (Switzerland)
Kaszycki *et al.* (2021)	Towards a bio-based circular economy in organic waste management and wastewater treatment – The Polish perspective	Journal Article	New Biotechnology
Khoshnevisan *et al.* (2021)	A critical review on livestock manure biorefinery technologies: Sustainability, challenges, and future perspectives	Journal Article	Renewable & Sustainable Energy Reviews
Kit Leong *et al.* (2021)	Reuniting the Biogeochemistry of Algae for a Low-Carbon Circular Bioeconomy	Journal Article	Trends in Plant Science
Klitkou *et al.* (2019)	From waste to value: Valorisation pathways for organic waste streams in circular bioeconomies	Book	From Waste to Value: Valorisation Pathways for Organic Waste Streams in Circular Bioeconomies
Kokkinos *et al.* (2020)	Circular bio-economy via energy transition supported by Fuzzy Cognitive Map modeling towards sustainable low-carbon environment	Journal Article	Science of The Total Environment
Kumar and Verma (2021)	Biomass-based biorefineries: An important architype towards a circular economy	Journal Article	Fuel
Ladu *et al.* (2020)	The role of the policy mix in the transition toward a circular forest bioeconomy	Journal Article	Forest Policy and Economics
Lange *et al.* (2021)	Developing a Sustainable and Circular Bio-Based Economy in EU: By Partnering Across Sectors, Upscaling and Using New Knowledge Faster, and For the Benefit of Climate, Environment & Biodiversity, and People & Business	Journal Article	Frontiers in Bioengineering and Biotechnology

Reference	Title	Type of Publication	Journal/Publisher
Lesage-Meessen *et al.* (2018)	Lavender- and lavandin-distilled straws: an untapped feedstock with great potential for the production of high-added value compounds and fungal enzymes	Journal Article	Biotechnology for Biofuels
Liu *et al.* (2021)	Sustainable blueberry waste recycling towards biorefinery strategy and circular bioeconomy: A review	Journal Article	Bioresource Technology
Loizides *et al.* (2019)	Circular bioeconomy in action: Collection and recycling of domestic used cooking oil through a social, reverse logistics system	Journal Article	Recycling
Lybæk and Kjær (2021)	Biogas Technology as an “Engine” for Facilitating Circular Bio-Economy in Denmark—The Case of Lolland & Falster Municipalities Within Region Zealand	Journal Article	Frontiers in Energy Research
Lybæk and Kjær (2022)	How Circular Bio-Economy Can Be Adopted within the Agro-Industry in Denmark by Cascading and Coupling Biomass Residues	Journal Article	GMSARN International Journal
Madadian *et al.* (2021)	From biorefinery landfills towards a sustainable circular bioeconomy: A techno-economic and environmental analysis in Atlantic Canada	Journal Article	Journal of Cleaner Production
Maina *et al.* (2017)	A roadmap towards a circular and sustainable bioeconomy through waste valorization	Journal Article	Current Opinion in Green and Sustainable Chemistry
Mak *et al.* (2020)	Sustainable food waste management towards circular bioeconomy: Policy review, limitations and opportunities	Journal Article	Bioresource Technology
Marcinek and Smol (2020)	Bioeconomy as one of the key areas of implementing a circular economy (CE) in Poland	Journal Article	Environmental Research, Engineering and Management
Mehta *et al.* (2021)	Advances in circular bioeconomy technologies: From agricultural wastewater to value-added resources	Journal Article	Environments - MDPI
Mengal *et al.* (2018)	Bio-based Industries Joint Undertaking: The catalyst for sustainable bio-based economic growth in Europe	Journal Article	New Biotechnology
Menon and Lyng (2021)	Circular bioeconomy solutions: driving anaerobic digestion of waste streams towards production of high value medium chain fatty acids	Journal Article	Reviews in Environmental Science and Biotechnology
Mikielewicz *et al.* (2020)	Current status, barriers and development perspectives for circular bioeconomy in Polish south Baltic area	Journal Article	Sustainability (Switzerland)
Mohan *et al.* (2016)	Waste Biorefinery: A New Paradigm for a Sustainable Bioelectro Economy	Journal Article	Trends in Biotechnology
Mohan *et al.* (2018)	Waste derived bioeconomy in India: A perspective	Journal Article	New Biotechnology
Moreira *et al.* (2021)	Role of microalgae in circular bioeconomy: from waste treatment to biofuel production	Journal Article	Clean Technologies and Environmental Policy
Morone and Imbert (2020)	Food waste and social acceptance of a circular bioeconomy: the role of stakeholders	Journal Article	Current Opinion in Green and Sustainable Chemistry
Mpofu *et al.* (2021)	Anaerobic treatment of tannery wastewater in the context of a circular bioeconomy for developing countries	Journal Article	Journal of Cleaner Production

Reference	Title	Type of Publication	Journal/Publisher
Muscat *et al.* (2021)	Principles, drivers and opportunities of a circular bioeconomy	Journal Article	Nature Food
Nagarajan *et al.* (2020)	Resource recovery from wastewaters using microalgae-based approaches: A circular bioeconomy perspective	Journal Article	Bioresource Technology
Nayha (2020)	Finnish forest-based companies in transition to the circular bioeconomy - drivers, organizational resources and innovations	Journal Article	Forest Policy and Economics
Negi *et al.* (2021)	Circular Bioeconomy: Countries' Case Studies	Book Chapter	Biomass, Biofuels, Biochemicals
Overturf *et al.* (2020)	Towards a more sustainable circular bioeconomy. Innovative approaches to rice residue valorization: The RiceRes case study	Journal Article	Bioresource Technology Reports
Pagliaro (2020)	Waste-to-wealth: The economic reasons for replacing waste-to-energy with the circular economy of municipal solid waste	Journal Article	Visions for Sustainability
Pan *et al.* (2021)	Anaerobic co-digestion of agricultural wastes toward circular bioeconomy	Journal Article	iScience
Paredes-Sanchez *et al.* (2019)	Evolution and perspectives of the bioenergy applications in Spain	Journal Article	Journal of Cleaner Production
Puyol *et al.* (2017)	Resource Recovery from Wastewater by Biological Technologies: Opportunities, Challenges, and Prospects	Journal Article	Frontiers in Microbiology
Qin *et al.* (2021)	Resource recovery and biorefinery potential of apple orchard waste in the circular bioeconomy	Journal Article	Bioresource Technology
Reim *et al.* (2019)	Circular Business Models for the Bio-Economy: A Review and New Directions for Future Research	Journal Article	Sustainability
Rekleitis *et al.* (2020)	Utilization of agricultural and livestock waste in anaerobic digestion (A.D): Applying the biorefinery concept in a circular economy	Journal Article	Energies
Sadhukhan *et al.* (2020)	Perspectives on "game changer" global challenges for sustainable 21st century: Plant-based diet, unavoidable food waste biorefining, and circular economy	Journal Article	Sustainability (Switzerland)
Salvador *et al.* (2021c)	Key aspects for designing business models for a circular bioeconomy	Journal Article	Journal of Cleaner Production
Santagata *et al.* (2021)	Food waste recovery pathways: Challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment	Journal Article	Journal of Cleaner Production
Santana *et al.* (2021)	Pelletizing of lignocellulosic wastes as an environmentally friendly solution for the energy supply: insights on the properties of pellets from Brazilian biomasses	Journal Article	Environmental Science and Pollution Research
Sarma *et al.* (2021)	Valorization of microalgae biomass into bioproducts promoting circular bioeconomy: a holistic approach of bioremediation and biorefinery	Journal Article	3 Biotech
Sefeedpari *et al.* (2020)	To What Extent Is Manure Produced, Distributed, and Potentially Available for Bioenergy? A Step toward Stimulating Circular Bio-Economy in Poland	Journal Article	Energies

Reference	**Title**	**Type of Publication**	**Journal/Publisher**
Sharma *et al.* (2021)	Sustainable processing of food waste for production of bio-based products for circular bioeconomy	Journal Article	Bioresource Technology
Sherwood (2020)	The significance of biomass in a circular economy	Journal Article	Bioresource Technology
Shirsath and Henchion (2021)	Bovine and ovine meat co-products valorisation opportunities: A systematic literature review	Journal Article	Trends in Food Science & Technology
Solis *et al.* (2020)	Multi-objective optimal synthesis of algal biorefineries toward a sustainable circular bioeconomy	Conference Paper	International Conference on Sustainable Energy and Green Technology 2019, SEGT 2019
Stegmann *et al.* (2020)	The circular bioeconomy: Its elements and role in European bioeconomy clusters	Journal Article	Resources, Conservation & Recycling: X
Taffuri *et al.* (2021)	Integrating circular bioeconomy and urban dynamics to define an innovative management of bio-waste: The study case of turin	Journal Article	Sustainability (Switzerland)
Temmes and Peck (2020)	Do forest biorefineries fit with working principles of a circular bioeconomy? A case of Finnish and Swedish initiatives	Journal Article	Forest Policy and Economics
Tsai and Lin (2021)	Analysis of promotion policies for the valorization of food waste from industrial sources in Taiwan	Journal Article	Fermentation
Tsegaye *et al.* (2021)	Food waste biorefinery: Pathway towards circular bioeconomy	Journal Article	Foods
Ubando *et al.* (2020)	Biorefineries in circular bioeconomy: A comprehensive review	Journal Article	Bioresource Technology
Usmani *et al.* (2021)	Lignocellulosic biorefineries: The current state of challenges and strategies for efficient commercialization	Journal Article	Renewable and Sustainable Energy Reviews
Vea *et al.* (2018)	Biowaste Valorisation in a Future Circular Bioeconomy	Journal Article	Procedia CIRP
Yi Leong *et al.* (2021)	Waste biorefinery towards a sustainable circular bioeconomy: a solution to global issues	Journal Article	Biotechnology for Biofuels
Zecevic *et al.* (2019)	A BUSINESS MODEL IN AGRICULTURAL PRODUCTION IN SERBIA, DEVELOPING TOWARDS SUSTAINABILITY	Journal Article	Ekonomika Poljoprivreda-Economics of Agriculture

Table A. 2 - Final portfolio for search string 2

Reference	Title	Type of Publication	Journal/Publisher
Brunnhofer *et al.* (2020)	The biorefinery transition in the European pulp and paper industry - A three-phase Delphi study including a SWOT-AHP analysis	Journal Article	Forest Policy and Economics
Carraresi and Broring (2021)	How does business model redesign foster resilience in emerging circular value chains?	Journal Article	Journal of Cleaner Production
Corcoran and Hunt (2021)	Capitalizing on harmful algal blooms: From problems to products	Journal Article	Algal Research
D'Amato *et al.* (2021)	Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs	Journal Article	Forest Policy and Economics
Donner and Radic (2021)	Innovative Circular Business Models in the Olive Oil Sector for Sustainable Mediterranean Agrifood Systems	Journal Article	Sustainability
Donner and Vries (2021)	How to innovate business models for a circular bio-economy?	Journal Article	Business Strategy and the Environment
Donner *et al.* (2020)	A new circular business model typology for creating value from agro-waste	Journal Article	Science of the Total Environment
Donner *et al.* (2021)	Critical success and risk factors for circular business models valorising agricultural waste and by-products	Journal Article	Resources Conservation and Recycling
EMF (2015)	Delivering the circular economy: A Toolkit for Policy Makers	Report	Ellen MacArthur Foundation
EMF (2016)	The New Plastics Economy: Rethinking the Future of Plastics	Report	Ellen MacArthur Foundation
EMF (2017a)	Cities in the Circular Economy: An initial Exploration	Report	Ellen MacArthur Foundation
EMF (2017b)	Urban Biocycles	Report	Ellen MacArthur Foundation
EMF (2019)	Cities and Circular Economy for Food	Report	Ellen MacArthur Foundation
EMF (2020a)	Financing the circular economy: Capturing the opportunity	Report	Ellen MacArthur Foundation
EMF (2020b)	The circular economy: a transformative Covid-19 recovery strategy: How policymakers can pave the way to a low carbon, prosperous future	Report	Ellen MacArthur Foundation
EMF (2021b)	The big food redesign: Regenerating Nature with the Circular Economy	Report	Ellen MacArthur Foundation
EMF (2021c)	Universal circular economy policy goals: Enabling the transition to scale	Report	Ellen MacArthur Foundation
Gatto and Re (2021)	Circular Bioeconomy Business Models to Overcome the Valley of Death. A Systematic Statistical Analysis of Studies and Projects in Emerging Bio-Based Technologies and Trends Linked to the SME Instrument Support	Journal Article	Sustainability
Gyalai-Korpos *et al.* (2018)	Bioeconomy opportunities in the danube region	Book Chapter	World Sustainability Series
Petit-Boix and Leipold (2018)	The circular economy and the bio-based sector - Perspectives of European and German stakeholders	Journal Article	Journal of Cleaner Production
Mohan *et al.* (2018)	Waste derived bioeconomy in India: A perspective	Journal Article	New Biotechnology

Reference	Title	Type of Publication	Journal/Publisher
Nayha (2019)	Transition in the Finnish forest-based sector: Company perspectives on the bioeconomy, circular economy and sustainability	Journal Article	Journal of Cleaner Production
Nayha (2021)	Backcasting for desirable futures in Finnish forest-based firms	Journal Article	Foresight
Negi *et al.* (2021)	Circular Bioeconomy: Countries' Case Studies	Book Chapter	Biomass, Biofuels, Biochemicals
Paes *et al.* (2019)	Organic solid waste management in a circular economy perspective - A systematic review and SWOT analysis	Journal Article	Journal of Cleaner Production
Rodias *et al.* (2021)	Water-Energy-Nutrients Synergies in the Agrifood Sector: A Circular Economy Framework	Journal Article	Energies
Ryabchenko *et al.* (2017)	Sustainable business modeling of circular agriculture production: Case study of circular bioeconomy	Journal Article	Journal of Security and Sustainability Issues
Salvador *et al.* (2021c)	Key aspects for designing business models for a circular bioeconomy	Journal Article	Journal of Cleaner Production
WBCSD (2019)	CEO Guide to the Circular Bioeconomy	Report	World Business Council for Sustainable Development

APPENDIX B - Structure of the Questionnaire

Structure of the Questionnaire – Part 2

In this section, you will be asked to assess whether the criteria used for setting apart the Business Models are suitable for such purpose.
Indicate for each Building Block whether each criterion should be kept or excluded.

In case new criteria should be added, please describe them in the text field at the end of each building block, writing down the name of the criteria and the alternatives within brackets, and use semicolons to separate different criteria, as follows:
New Criterion 1 (alternative 1, alternative 2); New Criterion 2 (alternative 1, alternative 2, alternative 3).

Table B. 1 - Structure of part 2 of the questionnaire

Reviewing and Assessing the Criteria for Assessment					
Building Block (BB)	**Criterion**	**Alternatives**	**Keep Criterion**	**Exclude Criterion**	**In case new criteria should be included, please describe them here:**
Users and Contexts	Nature of product offer	[Product; Service]			
	Immediate customer	[Business-to-business (B2B); Business-to-consumer (B2C)]			
Value proposition	Market strategy	[Low cost; Differentiation; Focus (market segmentation)]			
	Production scale	[Specialty products; Production in bulk]			
Revenues	Nature of revenue	[Product-based / short-term profitability; Service-based / long-term profitability]			
	Impact of revenue	[Generating revenue for the company; Generating revenue for the company and for partners]			
Costs	Nature of costs	[Fixed costs; Variable costs]			
	Origin of costs	[Investment costs; Operational costs]			
Mission	Mission driver	[Environment-driven; Economy-driven; Socially-driven; Innovation/technology-driven]			

Reviewing and Assessing the Criteria for Assessment

Building Block (BB)	Criterion	Alternatives	Keep Criterion	Exclude Criterion	In case new criteria should be included, please describe them here:
Key activities	Type of activity	[Research & Development & Innovation; Marketing/Commercial; Operational; Management]			
Partners	Type of partner	[Academia/University; Industry/Company; Government/Public organisation]			
	Position of partner in the value chain	[Upstream; Downstream]			
Natural resources	Origin of natural resources	[Primary-use natural resources; Non-primary-use natural resources]			
Technical resources	Ownership of technical resources	[Own; Shared with partners; Outsourced]			
Energy resources	Origin of energy resources	[Re-using resources to generate energy within the company; Acquiring energy (in the desired form - electricity, gas, etc.) sources from outside the company]			
Next use	End-of-life management	[Upcycling; Downcycling; Sound disposal]			
Distribution	Immediate customer	[Business-to-business (B2B); Business-to-consumer (B2C)]			
Positive Impacts	Dimension of positive impacts	[Environmental; Economic; Social]			
Negative Impacts	Dimension of negative impacts	[Environmental; Economic; Social]			

Structure of the Questionnaire – Part 3

From questions 19 through 32, please consider the following:

How representative of the strategies for implementing/managing the Business Model *Optimising Resource Efficiency and Use*, in the context of a Circular Bioeconomy, is the FIRST alternative in comparison to the SECOND one (considering the criterion within brackets)?

“Optimising resource efficiency and use” helps narrow and slow resource flows. It aims to use as little of a resource as possible relative to a certain product output and reduce or eliminate the generation of waste.
This Business Model allows reducing the inputs of either primary or non-primary resources per unit of final product both at the production or manufacturing phase and at the use phase. Strategies to put this business model into practise include from making a product as lean as possible during its production (e.g., lean manufacturing) to making products fulfil their intended use to the greatest and most comprehensive extent (e.g., making a product last as much as possible at the use phase – high-quality and long-lasting products –, or enable sharing to avoid waste – sharing food to prevent food waste).

Table B. 2 - Structure of part 3 of the questionnaire

Optimising Resource Efficiency and Use										
Building Block (BB)	**Pair Comparison**	**Extremely less representative**	**Much less representative**	**Less representative**	**Moderately less representative**	**Equally representative**	**Moderately more representative**	**More representative**	**Much more representative**	**Extremely more representative**
Users and Contexts	PRODUCT in relation to SERVICE (considering the nature of product offer)									
	BUSINESS-TO-BUSINESS in relation to BUSINESS-TO-CONSUMER (considering the immediate customer)									
Value proposition	LOW COST in relation to DIFFERENTIATION (considering the market strategy)									
	LOW COST in relation to FOCUS (considering the market strategy)									
	DIFFERENTIATION in relation to FOCUS (considering the market strategy)									
	SPECIALTY PRODUCTS in relation to BULK PRODUCTION(considering the production scale)									
Revenues	PRODUCT-BASED in relation to SERVICE-BASED (considering the nature of revenue)									

Optimising Resource Efficiency and Use										
Building Block (BB)	**Pair Comparison**	**Extremely less representative**	**Much less representative**	**Less representative**	**Moderately less representative**	**Equally representative**	**Moderately more representative**	**More representative**	**Much more representative**	**Extremely more representative**
	GENERATING REVENUE FOR THE COMPANY in relation to GENERATING REVENUE FOR THE COMPANY AND FOR PARTNERS (considering the impact of revenue)									
Costs	FIXED COSTS in relation to VARIABLE COSTS (considering the nature of costs)									
	INVESTMENT COSTS in relation to OPERATIONAL COSTS(considering the origin of costs)									
Mission	ENVIRONMENT-DRIVEN in relation to ECONOMY-DRIVEN (considering the mission driver)									
	ENVIRONMENT-DRIVEN in relation to INNOVATION/TECHNOLOGY-DRIVEN (considering the mission driver)									
	ENVIRONMENT-DRIVEN in relation to SOCIALLY-DRIVEN (considering the mission driver)									
	ECONOMY-DRIVEN in relation to SOCIALLY-DRIVEN (considering the mission driver)									
	ECONOMY-DRIVEN in relation to INNOVATION/TECHNOLOGY-DRIVEN (considering the mission driver)									
	SOCIALLY-DRIVEN in relation to INNOVATION/TECHNOLOGY-DRIVEN (considering the mission driver)									
Key activities	RESEARCH & DEVELOPMENT & INNOVATION in relation to MARKETING/COMMERCIAL (considering the type of activity)									
	RESEARCH & DEVELOPMENT & INNOVATION in relation to OPERATIONAL (considering the type of activity)									
	RESEARCH & DEVELOPMENT & INNOVATION in relation to MANAGEMENT (considering the type of activity)									
	MARKETING/COMMERCIAL in relation to OPERATIONAL (considering the type of activity)									
	MARKETING/COMMERCIAL in relation to MANAGEMENT (considering the type of activity)									

Optimising Resource Efficiency and Use										
Building Block (BB)	**Pair Comparison**	**Extremely less representative**	**Much less representative**	**Less representative**	**Moderately less representative**	**Equally representative**	**Moderately more representative**	**More representative**	**Much more representative**	**Extremely more representative**
	OPERATIONAL in relation to MANAGEMENT (considering the type of activity)									
Partners	ACADEMIA/UNIVERSITY in relation to INDUSTRY/COMPANY (considering the type of partner)									
	ACADEMIA/UNIVERSITY in relation to GOVERNMENT/PUBLIC ORGANISATION (considering the type of partner)									
	INDUSTRY/COMPANY in relation to GOVERNMENT/PUBLIC ORGANISATION (considering the type of partner)									
	UPSTREAM in relation to DOWNSTREAM (considering the position of partner in the value chain)									
Natural resources	PRIMARY RESOURCES in relation to NON-PRIMARY RESOURCES (considering the origin of natural resources)									
Technical resources	OWN in relation to SHARED WITH PARTNERS (considering the ownership of technical resources)									
	OWN in relation to OUTSOURCED (considering the ownership of technical resources)									
	SHARED WITH PARTNERS in relation to OUTSOURCED (considering the ownership of technical resources)									
Energy resources	RE-USING RESOURCES TO GENERATE ENERGY WITHIN THE COMPANY in relation to ACQUIRING ENERGY (in the desired form - electricity, gas, etc.) FROM OUTSIDE THE COMPANY (considering the origin of energy resources)									
Next use	UPCYCLING in relation to DOWNCYCLING (considering the end-of-life management)									
	UPCYCLING in relation to SOUND DISPOSAL (considering the end-of-life management)									
	DOWNCYCLING in relation to SOUND DISPOSAL (considering the end-of-life management)									
Distribution	BUSINESS-TO-BUSINESS in relation to BUSINESS-TO-CONSUMER (considering the immediate customer)									

Optimising Resource Efficiency and Use										
Building Block (BB)	**Pair Comparison**	**Extremely less representative**	**Much less representative**	**Less representative**	**Moderately less representative**	**Equally representative**	**Moderately more representative**	**More representative**	**Much more representative**	**Extremely more representative**
Positive Impacts	ENVIRONMENTAL in relation to ECONOMIC (considering the dimension of positive impacts)									
	ENVIRONMENTAL in relation to SOCIAL (considering the dimension of positive impacts)									
	ECONOMIC in relation to SOCIAL (considering the dimension of positive impacts)									
Negative Impacts	ENVIRONMENTAL in relation to ECONOMIC (considering the dimension of negative impacts)									
	ENVIRONMENTAL in relation to SOCIAL (considering the dimension of negative impacts)									
	ECONOMIC in relation to SOCIAL (considering the dimension of negative impacts)									

The structure presented in

Table B. 2 was then replicated to the remaining six BMCBEs (one in each page of the questionnaire) accompanied by a description of the respective BMCBE as presented in section 4.4.

APPENDIX C - List of Projects and Publications During PhD

Research Projects During PhD

Table C. 1 - Projects in which the researcher participated during his PhD

Period	Project Details
2019-2021	**Title: Life Cycle Assessment (LCA) for Environmental Product Declaration (EPD) of Pork Meat Products** Description: The project consisted of developing LCA studies for Environmental Product Declarations (EPD) of 6 Pork Meat products (ham, bacon, salami, sausage, and 2 other fresh cuts) from the Castrolanda Cooperative. These were the first EPDs of pork meat products worldwide. Role: main researcher; Coordinator: Cassiano Moro Piekarski Sponsor: Castrolanda – Agroindustrial Cooperative Ltd.
2019-2021	**Title: Life Cycle Inventories of Cow Milk and Biogas from Dairy Cattle Manure** Description: The project aimed to build four life cycle inventories: (i) Milk production, from cow, semi-confined system, Zona da Mata region, MG, BR; (ii) Milk production, from cow, semi-confined system, Central-eastern mesoregion of Paraná, PR, BR; (iii) Milk production, from cow, confined system, Central-eastern mesoregion of Paraná, PR, BR, and; (iv) Biogas production, at biogas plant, PR, BR. Role: main researcher. Coordinator: Cassiano Moro Piekarski. Sponsor: National Council for Scientific and Technological Development (CNPq)

Publications During PhD

Table C. 2 - Publications in which the researcher participated during his PhD

JOURNAL ARTICLE CLOSELY RELATED TO THE THEME OF THIS DISSERTATION
Salvador, R., Barros, M. V., Freire, F. M. C. S., Halog, A., Piekarski, C. M., de Francisco, A. C. (2021a). Circular Economy Strategies on Business Modelling: Identifying the Greatest Influences. **Journal of Cleaner Production**, 299, 126918. https://doi.org/10.1016/j.jclepro.2021.126918 Salvador, R., Puglieri, F. N., Halog, A., de Andrade, F. G., Piekarski, C. M., & Antonio, C. (2021c). Key aspects for designing business models for a circular bioeconomy. **Journal of Cleaner Production**, 278, 124341. https://doi.org/10.1016/j.jclepro.2020.124341 Barcelos, S. M. B. D., Salvador, R., Barros, M. V., de Francisco, A. C., Guedes G. (2021). Circularity of Brazilian silk: promoting a circular bioeconomy in the production of silk cocoons. **Journal of Environmental Management**, 296, 113373. https://doi.org/10.1016/j.jenvman.2021.113373 Arias, A., González-Rodríguez, S., Barros, M. V., Salvador, R., de Francisco, A. C., Piekarski, C. M., Moreira, M. T. (2021). Recent developments in bio-based adhesives from renewable natural resources. **Journal of Cleaner Production**, 314, 127892. https://doi.org/10.1016/j.jclepro.2021.127892

Barros, M. V., Salvador, R., do Prado, G. F., de Francisco, A. C., & Piekarski, C. M. (2021). Circular economy as a driver to sustainable businesses. **Cleaner Environmental Systems**, 2, 100006. https://doi.org/10.1016/j.cesys.2020.100006

Barros, M. V., Salvador, R., de Francisco, A. C., & Piekarski, C. M. (2020). Mapping of research lines on circular economy practices in agriculture: From waste to energy. **Renewable and Sustainable Energy Reviews**, 131, 109958. https://doi.org/10.1016/j.rser.2020.109958

IN PRESS JOURNAL ARTICLES CLOSELY RELATED TO THE THEME OF THE DISSERTATION

Salvador, R., Pereira, R. B., Sales, G. F., Oliveira, V. C. G., Halog, A., De Francisco, A. C. (2021b). *In Press*. Current panorama, practice gaps, and recommendations to accelerate the transition to a circular bioeconomy in Latin America and the Caribbean. **Circular Economy and Sustainability**.

JOURNAL ARTICLES NOT CLOSELY RELATED TO THE THEME OF THE DISSERTATION

Salvador, R., Barros, M. V., do Prado, G. F., Pagani, R. N., Piekarski, C. M., & de Francisco, A. C. (2021). Knowledge and technology transfer in sustainability reports: Fomenting stakeholder engagement for sustainable development. **Corporate Social Responsibility and Environmental Management**, 28(1), 251-264. https://doi.org/10.1002/csr.2046

Salvador, R., Barros, M. V., dos Santos, G. E. T., van Mierlo, K. G., Piekarski, C. M., & de Francisco, A. C. (2021). Towards a green and fast production system: Integrating life cycle assessment and value stream mapping for decision making. **Environmental Impact Assessment Review**, 87, 106519. https://doi.org/10.1016/j.eiar.2020.106519

Jesus, R. H. G., Barros, M. V., Salvador, R., Souza, J. V., Piekarski, C. M., de Francisco, A. C. (2021). Forming clusters based on strategic partnerships and circular economy for biogas production: a GIS analysis for optimal location. **Biomass and Bioenergy**, 150, 106097. https://doi.org/10.1016/j.biombioe.2021.106097

França, W. T., Barros, M. V., Salvador, R., de Francisco, A. C., Moreira, M. T., & Piekarski, C. M. (2021). Integrating life cycle assessment and life cycle cost: a review of environmental-economic studies. **The International Journal of Life Cycle Assessment**, 1-31. https://doi.org/10.1007/s11367-020-01857-y

Franco, A. C., Franco, L. S., Tesser, D. P., Salvador, R., de Francisco, A. C., Picinin, C. T., & Piekarski, C. M. (2021). Advances and challenges on the technologies and applications of biomethane. **Energy Sources, Part A: Recovery, Utilization, and Environmental Effects**. https://doi.org/10.1080/15567036.2021.1899341

Franco, A. C., Franco, L. S., Tesser, D. P., Salvador, R., Piekarski, C. M., Picinin, C. T., & Puglieri, F. N. (2021). Benefits and barriers for the production and use of biomethane. **Energy Sources, Part A: Recovery, Utilization, and Environmental Effects**. https://doi.org/10.1080/15567036.2021.2009940

Ferreira, M. B., Salvador, R., Barros, M. V., de Souza, J. T., Rabelo, T. G. L., de Francisco, A. C., Coelho, R., & Piekarski, C. M. (2020). Eco-efficiency of the differential ratio change in a heavy-duty vehicle and implications for the automotive industry. **Sustainable Production and Consumption**, 21, 145-155. https://doi.org/10.1016/j.spc.2019.12.005

Barcelos, S. M. B. D., Salvador, R., Guedes, M. D. G., & de Francisco, A. C. (2020). Opportunities for improving the environmental profile of silk cocoon production under Brazilian conditions. **Sustainability**, 12(8), 3214. https://doi.org/10.3390/su12083214

Puglieri, F. N., Ometto, A. R., Salvador, R., Barros, M. V., Piekarski, C. M., Rodrigues, I. M., & Diegoli Netto, O. (2020). An environmental and operational analysis of quality function deployment-based methods. **Sustainability**, 12(8), 3486. https://doi.org/10.3390/su12083486

Prado, G. F., Piekarski, C. M., da Luz, L. M., de Souza, J. T., Salvador, R., & de Francisco, A. C. (2020). Sustainable development and economic performance: Gaps and trends for future research. **Sustainable Development**, 28(1), 368-384. https://doi.org/10.1002/sd.1982

PUBLISHED BOOK CHAPTERS

Suarez, F. S., Ortolani, J. M., Barros, M. V., Salvador, R., Araújo, C. K. C., Puglieri, F. N., Tesser, D. P. (2021). **Opportunities For Circular Initiatives Via Waste Recovery In The Region Of Campos Gerais – Brazil**. Handbook of Solid Waste Management: Sustainability through Circular Economy. https://doi.org/10.1007/978-981-15-7525-9_81-1

Piekarski, C. M., Barros, C. M., Salvador, R., Puglieri, F. N., Coelho, F. Q., Kiss, B. C. K. (2021). **Communication and Environmental Labeling**. Life Cycle Engineering and Management of products. https://doi.org/10.1007/978-3-030-78044-9_13

Pinheiro, E., Salvador, R., de Francisco, A. C., Piekarski, C. M., Halog A. (2021). **Incorporating Consumer Perspective Into the Value Creation Process in the Fashion Industry: a Path to Circularity**. Sustainable Fashion and Textiles in Latin America. https://doi.org/10.1007/978-981-16-1850-5_12

Barcelos, S. M. B. D., Salvador, R., Guedes, G., Pinheiro, E., Piekarski, C. M., de Francisco, A. C. (2021). **Socioeconomic and Environmental Aspects of the Production of Silk Cocoons in the Brazilian Sericulture**. Sustainable Fashion and Textiles in Latin America. https://doi.org/10.1007/978-981-16-1850-5_1

Salvador, R., & Barros, M. V. **Pollution Prevention and Control Strategies, Implications and Challenges**. (2020). Encyclopedia of the UN Sustainable Development Goals. https://doi.org/10.1007/978-3-319-71062-4_99-1

do Rosário, J. G. D. P., Salvador, R., Barros, M. V., Piekarski, C. M., da Luz, L. M., & de Francisco, A. C. (2020). **A Review on Multi-criteria Decision Analysis in the Life Cycle Assessment of Electricity Generation Systems**. International Business, Trade and Institutional Sustainability, 575-590. https://doi.org/10.1007/978-3-030-26759-9_33

BOOK CHAPTERS ACCEPTED FOR PUBLICATION

Salvador, R., Barros, M. V., Huarachi, D. A. R., Jesus, R. H. G., Piekarski, C. M., de Francisco, A. C. Life Cycle Assessment Assisting Decision-making Towards Sustainable Businesses. Life Cycle Assessment: New Developments and Multi-Disciplinary Applications. Accepted for publication in 2020.

TECHNICAL REPORTS SENT TO COMPANIES AND STAKEHOLDERS WHO PARTICIPATED IN THE DIFFERENT STAGES OF THIS RESEARCH

Salvador, Rodrigo. (2021). **Barriers, challenges, drivers, and opportunities for increased circularity in regional bioeconomy systems in Africa, America, Australia, and Europe** (Technical Report, Universidade Tecnológica Federal do Paraná).

Salvador, Rodrigo. (2021). **Business Models for a Circular Bioeconomy**: Making use of the B2Circle Tool – Report o Organisation X (Technical Report, Universidade Tecnológica Federal do Paraná).

Refereeing During PhD

Table C. 3 - Journals for which the researcher volunteered as a referee and number of reviews during his PhD

Period	Journal	Number of reviews completed
2021 - current	AIMS Energy	1
2021 - current	Cleaner Engineering and Technology	2
2021 - current	European Journal of Engineering Education	1
2021 - current	Frontiers in Public Health	1
2021 - current	Frontiers in Sustainability	1
2021 - current	Philosophical Transactions of the Royal Society A - Mathematical Physical and Engineering Sciences	2
2021 - current	Renewable Energy	1
2021 - current	Rhizosphere	1
2021 - current	Scientific Reports	2
2021 - current	Sustainability	1
2020 - current	Cleaner Environmental Systems	3
2019 - current	Environmental Progress & Sustainable Energy	8
2019 - current	Journal of Cleaner Production	37