Master Thesis

Innovation & Entrepreneurship

Closing loops through Industrial Symbiosis

An exploration of how Dutch microbreweries can convert their wastes into resources through Industrial Symbiosis in a Circular Economy.

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Abstract

The transition from a linear to a circular economy has increasingly gained attention over the past decade. An important aspect of this transition can be found in closing material loops. This research aimed to explore how Dutch microbreweries can convert their wastes into resources by cross-industrial collaborations, also called Industrial Symbiosis (IS). A case study has been conducted to find out why companies engage in circular practices, and an in-depth analysis was conducted to explore which conditions influence the emergence of Industrial Symbiosis, and whether they hinder or facilitate the process. Findings show that ecological motives were dominant over economic motives, which contradicts the general belief IS is a result of companies seeking for competitive advantage driven by economic incentives. In terms of the emergence process, it became apparent cases experienced multiple different barriers, overshadowing the enabling factors. This is partially caused by the small scales of the companies. Overall, this study provided an overview of the most important factors affecting the emergence of IS, including 32 propositions proving additional context. Furthermore, it emphasizes the importance of facilitators to share knowledge and best practices, as well as platforms to connect different actors in order to make waste-valuation work for SMEs.

Keywords: drivers and barriers towards Industrial Symbiosis, waste-valuation, waste-to-resource activities, closed-loop production systems, cross-industrial collaborations, circular economy.

Preface

In 2016, during his Environmental Sociology course at Loyola University in New Orleans, professor Anthony E. Ladd made me realize the societal and ecological consequences of modern value propositions. They often favor an underlying treadmill of consumption and the utopia of infinite growth as a driving force behind commercial successes. An economic perspective which radically changed my view on the meaning of value creation, and raised my interest in organizational sustainability matters. Subsequentially, I wanted to dedicate my thesis to a sustainability topic. Hereby, I present you the result.

Way before the start of this project, I already chose to stick with a quantitative research method. Here I am, several months and eight interviews later. Although I cannot deny it has been quite a challenge not to get lost in all the qualitative data, I have to admit that the decision to conduct a case study has actually made this project a lot more fun. Heading out for a day to interview fellow beer-enthusiasts was always a joy, particularly in times of a pandemic.

To all brewers, I would like to express my sincere gratitude for showing me around your companies, being so kind and patient to answer countless questions about the brewery and many beer-related matters that had nothing to do with the purpose of this study. I really enjoyed conversating with you, and familiarizing with your wonderful products gave me an even better understanding of your philosophies. You all do a very great job and I admire the work you put into your companies and the transition towards a more sustainable beer industry.

This master thesis was the last obstacle towards graduation and there are some people I want to thank individually for their support during this very challenging project. Jurian, after countless walks, phone calls, and (academic) discussions, you are probably even more familiar with the topic of this thesis than I am. A massive thanks for always being there to help me out when I was stuck. Now it is my turn to kindly push you towards the completion of your last academic hobby project, so there is no need to celebrate yet. Carolien and Jeroen, massive thanks for your generous support despite of your busy schedules as well! I appreciate it a lot. Sophie, my apologies for my never ending and way too detailed monologues about loops and stuff. Thanks for not running away from me. I also want to thank Karen. You put a lot of time and effort into helping me while writing this thesis, often during evenings or weekends and particularly within the last weeks of the project. Although we never had an opportunity to meet in person, I always felt supported in the process. Thanks a lot, and enjoy the Christmas break.

Finally, I want to thank the Radboud University in general for providing me an absolutely marvelous time as a student in Nijmegen. Hopefully, my decade of financial support contributed to an even more prosperous future, enriching the academic world with lots of new knowledge.

Best,
Dries van Rens

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Chapter 1: Introduction

1.1 Introduction

The world's rapid population growth and its consumption patterns are increasingly putting pressure on the planet's ecological and social boundaries, impacting both human well-being as well as the Earth's biophysical thresholds (Leach, Raworth, & Rockström, 2013; Rockström et al., 2009). The population rate is expected to reach 9.8 billion humans in the year 2050, compared to 7.8 billion in 2019 (United Nations Department of Economic & Social Affairs, 2019). If this happens, three planets will be needed by 2050 to support our current lifestyle (United Nations, n.d.). The increasing human consumption is highlighted by the fact the gross domestic product (GDP) grows even faster than the population. Both factors combined are considered the dominant drivers of resource extraction, which in turn accounts for over half of the global greenhouse gas emissions (Oberle et al., 2019). In addition, global waste production is about to double by 2050, and only 31% of the potential 75% of the European and Central Asian waste is recovered (Kaza, Yao, Bhada-Tata, & Van Woerden, 2018). Radical changes of consumption and production patterns are needed to prevent future ecological overshoot. Implementing principles of the Circular Economy (CE) in businesses can contribute to a reduction of emissions, waste streams, and resource exhaustion, and in turn, prevent an ecological overshoot (Brennan, Tennant, & Blomsma, 2015).

1.2 The Circular Economy

Over the last decade, the concept of the CE has gained an increasing amount of attention in the field of policymaking, academics, consultancy, and law, resulting in a 50% growth of scientific publications (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Reike, Vermeulen, & Witjes, 2018). The Circular Economy is a system in which energy and material loops are created to maximize value retention and minimize waste. This as opposed to the conventional linear economy, in which resources are extracted, converted into products, used by a consumer, and disposed when not considered of value anymore (Ellen MacArthur Foundation, 2013). The CE has widely been associated with the 3R-imperative, referring to maximizing resource value retention by *Reuse*, *Reduce*, and *Recycle* strategies. However, over time the number of different R's mentioned in academics increased and their definitions started to vary, enlarging the scope of the concept (Reike et al., 2018; Winans, Kendall, & Deng, 2017).

While the CE is widely seen as a sustainability concept, the benefits of the CE businesses are not limited to environmental gains. Because manufacturing businesses spend 40% of their budget on materials, boosting resource efficiency can increase profit margins and makes them less vulnerable to price fluctuations of resources (European Commission, 2020). Besides, circularity principles can boost customer loyalty and retention and reduce product complexity (Ellen MacArthur Foundation, 2013). At a European economical level, it is estimated to generate 700.000 new jobs and increase the European GDP by 0.5 percent by 2030 (European Commission, 2020). It is not without reason that the European Union introduced the Circular Economy Action plan in 2015 to stimulate a circular transition.

1.3 Problem statement

The concept of the CE has clear environmental, social, and ecological advantages. However, the implementation is complex and has severe implications for the way businesses operate. The transition from a linear to a circular economy also impacts companies manufacturing processes, business plans and supply chains (Bocken, De Pauw, Bakker, & Van Der Grinten, 2016; Brennan et al., 2015; Geissdoerfer et al., 2017). It essentially requires companies to close material loops. On a large scale, this can only successfully be done by a connection between suppliers and producers and between companies and different industries (Winkler, 2011). Thus, a company cannot become circular on its own. More collaboration between actors is necessary to reach disruptive change (Ritzén & Sandström, 2017; Winkler, 2011). Even though business-collaborations in general are widely explored in science, specific research on the implementation in a CE is rare and needs further exploration (Dora, 2019). This is problematic, since a shift towards circularity will be obstructed as long as firms do not know how they can successfully cooperate within a CE to close material loops. Industrial Symbiosis (IS) is a stream within Industrial Ecology which specifically focusses on how a firms' wastes can be used as raw materials by another firm through collaborations with mutual benefits, reaching both environmental, social, and ecological benefits (Neves, Godina, G. Azevedo, Pimentel, & C.O. Matias, 2019). Although Domenech, Bleischwitz, Doranova, Panayotopoulos, and Roman (2019) consider IS to play a crucial role in the transition towards a CE, little is known about under which conditions IS can contribute to closed loop production in practice. Therefore, the aim of this research is to explore how Dutch microbreweries can convert their wastes into resources through IS in a CE. This research can provide a starting point for companies to move towards circularity by providing recommendations to create favorable conditions to close loops through IS.

This research focusses on commercial Dutch microbreweries for several reasons. First, previous research has shown that the enablers and barriers of Industrial Symbiosis largely vary per industry (Henriques, Ferrão, Castro, & Azevedo, 2021) and region (Madsen, Boisen, Nielsen, & Tackmann, 2015). Therefore, assessing one specific sector enhances the generalizability within the industry as a whole, and a regional focus can foster an actual transition in practice. Second, the beer industry has a severe ecological impact due to the large amounts of water and grains used in the brewing process, as well as its high carbon dioxide emissions during the fermentation process. The choice for microbreweries in particular is based on previous research indicating microbreweries are running behind of their large counterparts in terms of ecological sustainability (Jones, 2018). Consequently, the central research question in this paper is:

How can Dutch microbreweries successfully contribute to a circular economy by closing material loops through Industrial Symbiosis?

This question will be answered using the following sub-questions:

1. Which circular efforts have already been made in the Dutch Microbrewery industry?
2. What motivates Dutch Microbreweries to make circular efforts?
3. What conditions hinder or accelerate Dutch Microbreweries to engage in Industrial Symbioses to close material loops?
4. How do these conditions relate to the process of Industrial Symbiosis emergence?

In this study, all organizational attempts to incorporate circular principles are considered a circular effort, regardless whether these attempts turn out successful or not. These principles will be explained in detail in the next chapter. The motives are the reasons why the breweries make these attempts, and closing loops refers to waste-to-resource activities through IS.

1.4 Practical and theoretical relevance

In the Netherlands alone, 24 million hectoliter of beer has been produced in 2016 (Nederlandse Brouwers, n.d.). With its large waste streams; energy, grains and fresh water use, and carbon dioxide emissions, the beer industry has a significant environmental impact (Olajire, 2020). The beer industry shows a trend in which the market is more and more fractured due to the large increase of microbreweries. From 2007 to 2017, the amount of breweries in the Netherlands grew from 90 to 370 (CBS, 2017). Due to rapid increase of microbreweries, its share of ecological impact is increasing as well. Even though the beer industry has made severe efforts to become more sustainable by carbon dioxide recovery and water and energy reduction (Staples, Reeling, Widmar, & Lusk, 2020), large breweries outperform microbreweries in terms of technological innovations (Jones, 2018) and consume less water and energy (Staples et al., 2020). However, circularity goes beyond sustainability improvements, and demands closed material loops. The brewing industries waste stream of grain remainders, yeast, and water have high potential to be converted into resources for different purposes.

However, cross-industrial collaborations to achieve converting waste into resources are still rare and sector-specific guidelines on how to orchestrate IS are lacking. This is a missed opportunity, since circular loops can only effectively be formed through collaborations across different industries (Winkler, 2011). Therefore, implementing IS can be seen as a tool towards closing material loops, contributing to a CE. Converting waste into resources through IS requires activities that impact the company's business model. For instance, new types of partnerships are necessary to link material streams, and transferring those materials to the right partner rather than trashing them requires new activities like logistics and quality monitoring. Therefore, there is a strong connection between IS and the CE. From an economic perspective, knowing how to successfully take away barriers of IS to convert waste into resources can help breweries to reduce costs and improve their image. From an environmental perspective, enhancing waste-to-resource options of current waste streams increases value retention and therefore lowers the extraction of resources and pollution.

This research contributes to the academical field in two ways. First, the outcomes will provide insights in how specific conditions that hinder or enable successful IS in the beer industry. Second, it further explores the conditions of IS in the context of closing loops. This is relevant because even though much attention has been paid to what a CE is, how it relates to different fields, and what are its generic enablers and barriers, these enablers and barriers highly depend on contextual conditions like the country and industry. More knowledge about IS networks in practice and how this impacts supply chains is needed (Geissdoerfer et al., 2017). This research will provide a starting point in this direction by combining conditions from the field of closed loop supply chain management with conditions influencing IS.

1.5 Research scope

This research specifically focusses on Dutch independent microbreweries that use their own brewing facilities. This excludes breweries that are part of larger subsidiaries like AB InBev and the Heineken Group, and breweries that rent production capacity at larger facilities to run their production since the latter have less control over the production process. The Brewers Association defines a microbrewery as a brewery with an annual production below 1,8 million hectoliters (Brewers association, n.d.). However, this definition does not take into account the independence which is relevant for this research since small breweries are running behind its larger counterparts. Therefore, a microbrewery will be defined as an independent brewery (not owned by or under supervision of another manufacturer of alcoholic beverages), with an annual production below 1,8 million HL, using its own brewing facilities. This excludes brewpubs and hobbyists.

1.6 Thesis outline

In the next chapter, the concepts CE and IS will be explained and linked. Based on this, a preliminary conceptual model will be constructed. In chapter 3, the case selection and methodology will be explained. This research is based upon semi-structured interviews and thus uses a qualitative approach. In chapter 4, the results of the interviews will be discussed and compared with the preliminary model based upon the literature study. Chapter 5 summarizes the conclusion that can be drawn from this research, including academical and practical implications. Finally, the limitations of this study will be assessed and suggestions for further research will be given.

Chapter 2: Theoretical Framework

2.1 The Circular Economy

The CE is a sustainability concept that is widely associated with the planetary boundaries approach to global sustainability that Rockström et al. (2009) described. They identified nine ecological thresholds that should not be exceeded in order to maintain a safe environment for humanity. Crossing these thresholds would potentially lead to radical environmental changes, threatening our existence. The *linear economy* – also called the "take-make-dispose" economy – puts these thresholds under pressure by extracting resources like materials and energy from the planet, converting them into products that are being consumed, and eventually disposing the wastes and emissions in nature when not considered of economic value anymore (Ellen MacArthur Foundation, 2013; Korhonen, Honkasalo, & Seppälä, 2018). As opposed to this unsustainable linear flow, the CE aims at maximizing value retention. This means producing and consuming in a way that materials and energy are used in the most efficient way through cascading and closed loop flows, and waste is minimized (Ellen MacArthur Foundation, 2013; Kalmykova, Sadagopan, & Rosado, 2018; Reike et al., 2018).

2.1.1 Principles of the Circular Economy

While its exact origin is not clear, the concept of the CE has already been discussed by practitioners in the 90's as a potential strategy to manage China's rapid economic growth and its environmental consequences (Winans et al., 2017). The CE is widely seen as a global concept of economic development in which ecological preservation would be respected by circulating natural resources. This is done by following the principles of the 3R-framework: *reducing* the use of natural resources, *reusing* products after the initial consumption, and *recycling* materials as many times as possible before they ultimately become waste (A. M. King, Burgess, Ijomah, & McMahon, 2006; Zhijun & Nailing, 2007). Over the last decade however, the attention in the field of policymaking, academics, consultancy, and law skyrocketed, resulting in a 50% increase of scientific publications about the CE (Reike et al., 2018). The Ellen MacArthur Foundation has made a major contribution to the CE by conceptualizing it in its Circular Economy Systems Diagram, also known as the Butterfly Model (see figure 1), and providing practical guidelines to a transition towards a CE in different industries. They describe the CE based on three core principles: designing out negative externalities like waste and pollution, optimize product and materials use, and regenerate natural systems (Ellen MacArthur Foundation, 2013, 2015, 2019). First, a summary of the three core principles as described by the Ellen MacArthur Foundation will be provided.

Principle 1: design out waste and pollution

The first principle is based on the design and use of economic activities and products. This has to do with resource efficiency and supply chain optimalization. As long as production processes involve materials which cannot be reused as an input for new cycles, waste production is inevitable. Wastes will eventually end up in landfills or the ecosystem in general, polluting the planet. However, when all components used are non-toxic and fit in biological or ecological loops, waste does not exist (Ellen MacArthur Foundation, 2013). Substituting harmful materials by renewable alternatives can help to achieve this goal. Creating products that serve its intended purpose with minimal use of resources, and manufacture them in a way that they can be repaired, upgraded or disassembled to enhance value recovery also contributes to the first principle (Ellen MacArthur Foundation, 2019). Supply chains can be optimized by using as little energy and resources as possible that do not end up in the final product, for instance by minimizing or factoring out packaging materials and transportation (Ellen MacArthur Foundation, 2019).

Principle 2: optimize product and material use

In a CE, resources are being used as efficient as possible while maintaining or cascading their value as long as possible. This requires two main efforts: using products as long as possible, and eventually circulate materials as long as possible (Ellen MacArthur Foundation, 2019). Rather than throwing away a product when it is not being used anymore, it may have the capacity to be reused for the same purpose or for different applications. If a product cannot be reused or repaired anymore, some components may still function fine and can be used again. Although extending product lifetimes has the largest impact on value retention, recirculating materials rather than using new virgin materials also contributes to a CE (Ellen MacArthur Foundation, 2019). It does not only prevent waste and unnecessary resource extraction; it also minimizes energy use. Recycling materials generally requires significantly less energy than running raw materials through the production process to create the same material again (Ellen MacArthur Foundation, 2019).

Principle 3: regenerate natural systems

The last principle relates to preventing environmental degradation. As Rockström et al. (2009) pointed out, humanity is increasingly putting pressure on the planet's ecosystem. Even though it has a limited capacity of restoring itself, exceeding its thresholds can result in severe ecological changes and in turn threaten the existence of humans and other species. The CE aims at respecting and complementing biological systems to prevent this from happening. It favors agricultural activities that enhances soil fertility without the need for synthetic interference (Ellen MacArthur Foundation, 2019).

Value retention

The term *value retention* plays a central role in the CE. The term refers to practices to minimalize or eliminate degradation of resources. As the publications about the CE increased, so did the different definitions, ways of value retention – often based on different R-imperatives – and its exact meanings (Kirchherr, Reike, & Hekkert, 2017; Reike et al., 2018). Next to the 3R-imperatives (reuse, reduce, and recycle), A. M. King et al. (2006) for instance, mention 4R's, referring to *repairing, reconditioning*, *remanufacturing*, and *recycling*, focusing specifically on product design and its lifecycle. The Ellen MacArthur's Butterfly Model also mentions *refurbishing,* which is explained as repairing a product and update the cosmetic appearance while generally offering a warranty on the full product (Ellen MacArthur Foundation, 2013). The different R's of circularity and what they exactly entail led to severe confusion amongst scholars, therefore Reike et al. (2018) took the effort of identifying, comparing, and structuring the most common R-imperatives in literature related to the CE across different fields, resulting in a conceptual framework containing 10 different value retention options: R0 *refuse*, R1 *reduce*, R2 *resell/reuse*, R3 *repair*, R4 *refurbish*, R5 *remanufacture*, R6 *re-purpose*, R7 *recycle materials*, R8 *recover energy*, and R9 *remine*. This framework can be seen as a hierarchical ladder, in which remining (R9) is considered the lowest order of value retention, while refusing (R0) is considered the highest order of value retention on the circularity ladder. However, this model has a strong focus on manufacturing products, rather than food, making it less suitable for the context of this study.

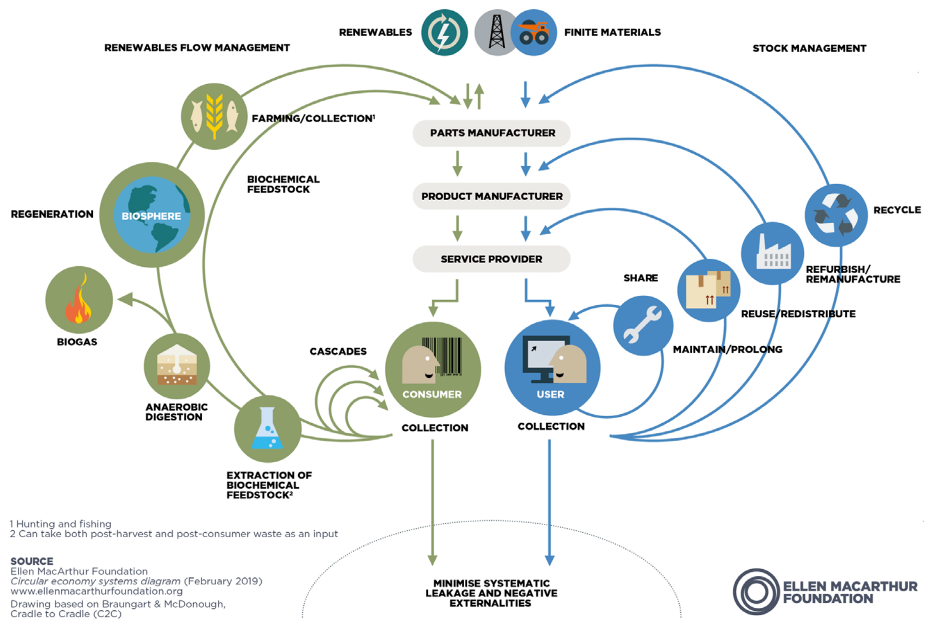


Figure 1: The Circular Economy Systems Diagram by Ellen MacArthur Foundation (2019)

2.1.2 Defining the Circular Economy

It is claimed by several authors (Geissdoerfer et al., 2017; Kirchherr et al., 2017; Schut, Crielaard, & Mesman, 2016) that the CE is most prominent and frequently defined as:

"An industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models." – (Ellen MacArthur Foundation, 2013, p. 7)

Even though this definition provides a global understanding of the CE, it does not take into account the different levels in which the CE can be assessed. The definition focusses on the industry in general, while practitioners are in need of guidance about how to adopt the CE concept (Kirchherr et al., 2017). Therefore, Kirchherr et al. (2017) analyzed 114 different definitions of the CE. First, they point out a distinction between the micro, meso, and macro-level is relevant. The micro level has to do with how an individual firm, a product, or the consumer has to change to become more circular (Kirchherr et al., 2017). The meso-level is concerned with the CE in a regional sense in which companies share its waste streams like materials, energy and water with others so they can use this as resources for their own processes. This has both mutual economic benefits, as well as ecological benefits and is known as *Industrial Symbiosis* (Neves et al., 2019; Prieto-Sandoval, Jaca, & Ormazabal, 2018). This topic will be further explained later. Finally, the macro-level focusses on the global or national level, or an entire industry (Kirchherr et al., 2017). Second, the Ellen McArthur Foundation's definition only puts emphasis on the 'restorative and regenerative' aspect of the circular economy, which only covers environmental gains. However, the benefits of a CE are not limited to ecological wins, but can also provide economic gains like material use and energy reductions and new market opportunities, as well as social gains like better well-being and stronger communities through sharing and cooperation (Kirchherr et al., 2017; Korhonen et al., 2018). Consequently, Kirchherr et al. (2017) define the CE as:

> *"An economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."* – (Kirchherr et al., 2017, pp. 224-225)

Both factors are relevant for this research since it focusses on small breweries and collaboration partners, rather than the entire economy or beer industry in general. Besides, due to their commercial nature, it is relevant to take both ecological as well as economic factors of the CE into account. In addition, closing material loops impacts waste and purchasing expenses and thus cannot be seen exclusively from an ecological perspective. Consequently, the definition of Kirchherr et al. (2017) will be used within this paper. It is important to point out the *circular economy* concept is strongly intertwined with the term *sustainability*. The CE is widely seen as a concept that can contribute to sustainability. Even though an exact distinction between what the CE and sustainability entails is debated, the field of CE strongly emphasizes resource efficiency, and material loops, while sustainability has a much larger scope. In literature, both terms have a social, economic, and ecological dimension. One cannot simply say that "becoming more sustainable" contributes to ecological benefits, since fighting global social inequality and injustice is also considered a sustainable development while it is questionable if it has any direct ecological consequences. However, the implementation of circular practices in a company to reduce material use and design out waste has direct ecological consequences. In turn, these ecological consequences may impact economic and social matters as well, but only to some extent. This paper solely focusses on the ecological aspects of circularity in the context of a company's resource use. More specifically, on closing material loops. Therefore, all references to sustainability within this study are connected to the ecological aspects of the term, which also forms the basis of the CE.

It is also important to stretch out, the term CE has become an umbrella term in scientific literature, relating to several fields, including business models, supply chain management, policy making, environmental science, product design, and many more (Merli, Preziosi, & Acampora, 2018; Reike et al., 2018). This makes the concept of the CE highly multidisciplinary. Even though many authors have done efforts to describe different disciplines within the circular economy, most attention went to conditions towards a CE, rather than how to implement these principles in practice. This is not surprising, since the global transition towards circularity has just begun and proven implementation concepts are starting to arise. There is also debate about the most suitable adoption approach: a top down in which policies and externalities stimulate or force a transition, or a bottom up approach in which firms move towards circularity on their own initiative (Ellen MacArthur Foundation, 2015).

2.2 Industrial Symbiosis and the Circular Economy

As explained in the previous section, the CE is about closing loops to maximize value retention to accomplish sustainable development. When trying to close material loops to prevent waste or unnecessary degradation of resources, it is important to look critical to what waste entails for an organization. What is considered a waste-stream for one company can potentially still be a useful resource for another. Therefore, converting waste into resources cannot effectively be done by a single company, but requires multiple companies across different industries to collaborate and connect their supply chains (Winkler, 2011). Industrial Symbiosis (IS) is a practical approach to achieve this and is considered an important strategy to make the transition from a linear to a CE (Domenech et al., 2019). The concept of IS originates from Industrial Ecology, a scientific stream that builds upon the idea that an industrial economy depends on and interacts with its biological surroundings. This happens through the process of planetary resource extraction, conversion, and the consequential disposal of wastes. Therefore, an industry should be designed in a way it maintains and respects the planets ecosystem (Chertow, 2000). IS is a stream within Industrial Ecology that focusses on the inter-organizational level exchange of resources. It can be defined as *"engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity"* (Chertow, 2000, p. 314).

Chertow, Ashton, and Espinosa (2008) describe three different opportunities of resource sharing through IS. First, firms can share and jointly manage utilities or infrastructures, often related to (waste)water, electricity, and heat. Second, firms can share ancillary services like security, cleaning, and transportation. Third, firms can exchange and reuse resources that are considered by-products to be used again as input for different applications across multiple industries. This can be as a substitute for raw materials, but it may also involve cascading, in which the quality requirements are decreasing along the resource flow (Chertow, 2007; Chertow et al., 2008). This can be achieved when activities and in- and outputs of industrial processes are complementary and underexploited (Chertow, 2007; Domenech Aparisi, 2010). This exchange increases value retention and resource efficiency since it extends material lifetimes and fosters multiple re-use cycles. At the same time, it decreases the generation of waste and emissions of greenhouse gasses. Thus, IS plays a crucial role in the road towards circularity (Domenech et al., 2019) and knowing how to overcome barriers of Industrial Symbiosis is needed in order to close material loops within a CE. Therefore, this research only focusses on the exchange of by-products opportunity of IS. Within an organization, this can either entail finding new uses for the produced outputs as well as replacing raw-material inputs by substitutes that are by-products of other activities and industries.

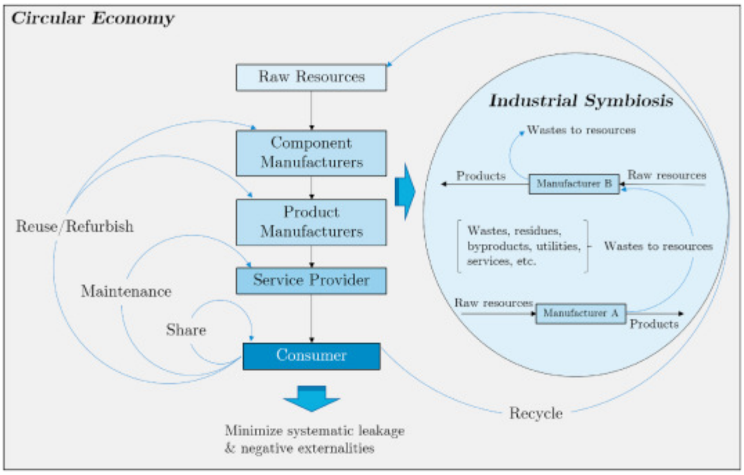


Figure 2: Industrial Symbiosis in relation to the Circular Economy, by: Yu, Yazan, Bhochhibhoya, and Volker (2021)

2.2.1 Organizational motives to apply Industrial Symbiosis

From an organizational perspective, there are several motives to apply IS. In literature, economical motives for applying IS are dominantly reported as the main organizational motive for self-organized IS. These economical motives have several underlying factors. Exchanging by-products with others rather than disposing them reduces costs associated with waste and it may even generate new income streams due to the higher perceived value and quality of the former waste-stream. For the receiving party, it can decrease the costs of input-purchases (Mirata & Emtairah, 2005). In addition, the increased resource efficiency makes organizations less vulnerable to resource scarcity (Chertow, 2007). Engaging in IS goes hand in hand with collective learning, often resulting in new (radical) innovations. Therefore, generating new business opportunities as a result of symbiotic innovation can also be a motive to engage in symbiotic networks (Doménech & Davies, 2011). Organizations can also have policy-driven motives to apply IS. Symbiotic activity can for instance be used as a tool to comply with legal requirements related to emissions and waste targets, as well as limitations on the maximum allowed use of resources (Chertow, 2007). Environmental motives to engage in IS are also present in literature. Some companies engage in IS to decrease the ecological impact of their industrial activities (Boons, Chertow, Park, Spekkink, & Shi, 2017). However, Costa and Ferrão (2010) stretch out the ecological motive is often influenced by contextual factors shaped by policy-makers, for instance as a result of environmental legislation or stimulants like subsidies.

2.2.2. Models of Industrial Symbiosis

IS requires networks to connect different actors in order to share resources. These networks can be organized in different ways. In literature, three types of IS networks are commonly described:

<u>Self-organized models</u>

In this model, IS organically appears when private actors organically start exchanging resources to reach specific goals like cost reductions. These exchanges are based on self-interest of all participating actors. During the emergence, the actors are mostly not aiming at setting up an IS network, nor are they aware of environmental benefits they collectively generate (Chertow, 2007). The most common example of a self-organized IS network is the case of the Kalundborg region. From the 60's until present, manufacturing firms within this region started to collaborate and exchange excessive resources like heat. Initially solely driven by rational economic choices like cost-reduction, but later also driven by the scarcity of water (Domenech Aparisi, 2010). Self-organized (also called bottom-up) IS networks are characterized by strong network ties and tend to be very successful on the long run, since all actors involved have their own interest to be part of the collaboration (Boons et al., 2017).

<u>Facilitated models</u>

Even though self-organized IS is often seen as the most effective way of organizing IS, not all organizations manage to find or undergo efforts to find organizations with residual resources and identify possibilities to use them in its own activities. This requires time, effort, and internal knowledge about firms across different industries, which is often challenging for individual actors. In the facilitated model, a third-party functions as a mediator to link different actors and promote and facilitate symbiotic opportunities (Costa & Ferrão, 2010). Facilitators can play a role in monitoring and shaping the contextual environment of firms to foster IS or to take away obstacles. This model also has downsides. First, facilitated IS depends on the openness of firms. Facilitators are dependent on different firms share knowledge and internal information regarding their processes in order to shape effective conditions and link individual firms in a way all parties benefit. Second, when the first link has been made, it generates competitive advantage for the firms involved. As a result, these firms may lose their incentive to continue sharing information with the facilitator, resulting in limited environmental gains (Patala, Salmi, & Bocken, 2020).

Planned models

In contrast to self-organized IS networks, planned models do not emerge naturally but are collaborations specifically designed with the purpose of sharing resources and infrastructures, often within a geographical industrial area (Domenech et al., 2019).

2.2.3 The emergence process of Industrial Symbiosis

Regardless of the model used, IS does not happen overnight (Boons, Spekkink, & Mouzakitis, 2011). Baas and Boons (2004) point out IS is a long-term process that starts with individual companies self-organizing ways to increase their efficiency using their networks. Over time, regional learning processes can lead to the discovery of much larger opportunities, resulting in the discovery of IS. Doménech and Davies (2011) divide the emergence of IS in three phases. In the *emergence phase*, companies explore simple cooperation opportunities and form initial informal ties with other actors. In the subsequential *probation phase*, the first exchanges take place to generate experience, trust and knowledge, and members learn to understand the dynamics of the network. In the *development and expansion phase*, the cooperation is further intensified and joined practices become embedded in the organizations. Mortensen and Kørnøv (2019) also explored the emergence of IS and identified three critical activities for the emergence of IS. These activities are dynamic and do not necessarily happen sequentially.

First, *creating awareness and interest in IS*, which entails providing incentives to engage in IS and spreading the concept and possibilities of IS. Policy changes can lead to economic benefits or discouraging unsustainable practices. Knowledge institutes play an important role in sharing objective information about technological opportunities, facilitating IS. Mortensen and Kørnøv (2019) mention creating awareness and interest in IS as one of the three core activities of the IS emergence process which happens within the organizational borders. However, as earlier work of Chertow (2007) makes clear, firms are mostly not aware of setting up, or being part of IS practices and its potential non-economic benefits. They simply seek for ways to obtain competitive advantage, driven by economic motives. The authors also explain that the becoming aware of symbiotic practices and possibilities is crucial for the further development of effective IS networks. This issue is also highlighted in literature about waste-valuation, focusing on how waste-streams can be utilized. As long as this concept is widely unknown, companies often do not exactly know their waste streams at all. As a result, they will not be able to identify the potential waste-opportunities and waste revaluation is unlikely to happen (Leder, Kumar, & Rodrigues, 2020).

Second, *reaching out and exploration of connections* refers to the selection of potential collaboration partners, as well as building up strong tie relationships. These activities cross organizational borders and require both trust and time. Last, *organizing* refers to the development of symbiotic practices and assessing their feasibility before the post-emergence in which infrastructure and coordination mechanisms are set up and symbiotic activities are established (Mortensen & Kørnøv, 2019).

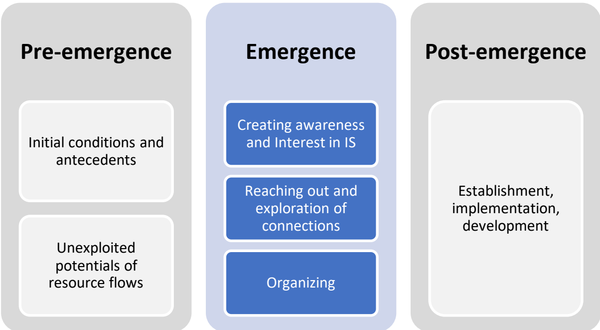


Figure 3: Conceptual model for IS emergence process, by Mortensen and Kørnøv (2019)

Azevedo et al. (2021) argue that unexpected barriers often occur during the emergence and implementation of IS because the existing systematic approaches that can be used to guide firms are incomplete. Therefore, they developed an alternative five-step implementation tool. This tool goes beyond the earlier work of Doménech and Davies (2011) and Mortensen and Kørnøv (2019) since it takes into account the full process starting from the exploration of IS benefits, to the actual strategic and technological implementation and long-term vision. Besides, it proposes concrete, systematic steps including practical and dedicated research questions firms need to address in every step of the tool. The sequential nature of this implementation tool emphasizes the importance of understanding intervening factors like motives, as well as enablers and barriers *before* moving on to the actual implementation process. Therefore, this study aims to identify and provide in-depth understanding of motives and conditions related to the emergence of IS amongst Dutch Microbreweries, including potential solutions to create favorable conditions. After clarifying the intervening factors, the implementation strategies can be developed, but the latter is beyond the scope of this research.

2.3 Conditions for successful Industrial Symbiosis collaborations

In the previous section, the different models and the IS emergence process of IS have been explained. The decision of organizations to seek for and implement symbiotic collaborations and the degree of success depends on many different conditions. In literature, much attention has been paid to motives, drivers, enablers, or facilitators that enhance IS emergence, and barriers that hinders IS (De Jesus &

Mendonça, 2018; Henriques et al., 2021; Neves et al., 2019). Even though there is quite some overlap between the different dimensions of conditions that affect the success of IS between different papers, the way how and when these conditions foster or obstruct reaching IS in practice, highly depend on contextual factors like the geographical region where firms are operating in as well as local legislations, the type of industry, and the resources used. Therefore, recommendations to overcome barriers for IS largely depend on the industry and it is crucial to take into account the local context when setting up guidelines for successful IS (Henriques et al., 2021; Madsen et al., 2015).

Therefore, a literature study is executed to map general barriers identified by scholars. These barriers will be explained and used as a starting point for the empirical study which aims to provide in-depth knowledge about the conditions that are specifically affecting IS emergence among Dutch microbreweries. This knowledge is important, since Azevedo et al. (2021) argue that understanding intervening factors is of great importance before being able to select and assess IS implementation strategies, followed by the technical implementation and scenario planning. Furthermore, some authors refer to 'conditions', while others use the terms 'enablers and barriers. An enabler is *"a factor that facilitates and supports the concretization of symbiotic synergies"*, while a barrier is *"a factor that hinders or obstructs the development of symbiotic synergies"* (Henriques et al., 2021, p. 7). Although the terms 'enablers' and 'barriers' provide more contextual information than speaking of a required 'condition', these terms can overlap. After all, if a specific condition is not being met, it can be seen as a barrier for IS emergence, but if the exact same condition is present, it may enable the emergence of IS. Therefore, the contextual factors influence if a condition is enabling or hindering IS emergence.

Both enablers and barriers can be divided over several different dimensions. De Jesus and Mendonça (2018) make a distinction between *soft* and *hard* types of enablers and barriers affecting circular activities. Economic and technological factors are considered *hard* types, while *soft* types relate to for instance social, regulatory, and management practices. As explained before, the enablers and barriers of IS differ a lot depending on the organization's context. Barriers for Industrial Symbiosis in general have been described by several authors, barriers of closed-loop production have also gained attention, primarily in the field of Circular Supply Chain Management (Kazancoglu, Kazancoglu, Yarimoglu, & Kahraman, 2020; Winkler, 2011). However, the combination of IS in de context of closing loops is still rare. In addition, elements that are specifically hindering IS in the Dutch beer industry are also not investigated yet.

In the next section, the outcomes of the literature study of the most prominent conditions will be addressed. Here, 'generic' conditions for successful symbiosis will be combined with conditions adapted from the fields of waste valuation and circular supply chain management. This way, this paper aims at combining both streams of literature. This is important since this research focusses specifically on closing resource loops making use of IS. A summary of the outcomes can be found in table 1.

Dimension	Condition	Source
Social	Trust	(Chertow, 2007; Neves et al., 2019)
	Willingness to cooperate	(Chertow, 2007; Neves et al., 2019)
	Knowledge about other firm's resources	(Chertow, 2007; Domenech Aparisi, 2010; Madsen et al., 2015)
	Short mental distance	(Domenech Aparisi, 2010; Kirchherr et al., 2018)
	Network diversity	(Neves et al., 2019)
Economic	Investment costs	(De Jesus & Mendonça, 2018; Mishra et al., 2018)
	Investment and profitability risks	(Geissdoerfer et al., 2017; Ritzén & Sandström, 2017)
	Waste disposal costs	(Henriques et al., 2021; Kazancoglu et al., 2020)
	Price of virgin materials	(Neves et al., 2019)
Technological	Availability of technological innovation	(De Jesus & Mendonça, 2018; Henriques et al., 2021)
	Material quality	(Domenech Aparisi, 2010; Henriques et al., 2021; Kazancoglu et al., 2020)
Policy - related	Obstructing or lacking legislations	(De Jesus & Mendonça, 2018; Neves et al., 2019)
	Bureaucratic procedures to obtain permits and certifications	(Henriques et al., 2021; Kazancoglu et al., 2020; Kirchherr et al., 2018)
Supply chain	Transportation complexity	(Hazen et al., 2021; Mishra et al., 2018)
	Limited availability and planning of received materials	(Kazancoglu et al., 2020; Leder et al., 2020)
	Collection and separation	(Kazancoglu et al., 2020)

Table 1: Outcomes of literature study on conditions impacting IS emergence

2.3.1 Social conditions

Industrial Symbiosis cannot be achieved without effective collaborations. Even though firms may have clear motives to seek for symbiotic collaborations, several social barriers appear in practice. Industrial Symbiosis requires knowledge and information sharing of internal processes in order to find opportunities to exchange resources and to optimize closed supply chains, resulting in waste reduction (Dora, 2019). This information may also entail trade secrets. However, *lack of trust* between the actors, or a business culture of *low willingness to cooperate* at all are often mentioned to obstruct successful symbiotic collaborations (Chertow, 2007; Neves et al., 2019). Both factors result in less information sharing and collaboration in general. Regardless of the underlying cause, a *lack of knowledge about other firms' resources and resources streams* forms another important barrier for IS. This is quite obvious, since improving the utilization of other firms' resources by using it to substitute own raw inputs can only be done if the actors know where to find them. The other way around, sharing by-products requires information about which companies can benefit from this (Chertow, 2007; Domenech Aparisi, 2010; Madsen et al., 2015).

Even when firms do want to collaborate and do not mind sharing internal information to integrate resource flows, the implementation requires actors to change or innovate operational processes. This does not happen overnight. Therefore, it is crucial to set long-term goals. This seems obvious, but it requires strategic alignment of the actors. This cannot be done when a shared vision, also referred to as *short mental distance* is lacking (Domenech Aparisi, 2010; Kirchherr et al., 2018). As Chertow (2000) points out, IS can only be successful if the underutilized assets the actors are sharing are complementary for the others' processes. For this reason, material exchanges or waste valuation generally happen in a cross-industrial setting. When a firm has *low network diversity*, it is much harder for a firm to find suitable collaboration partners, since companies with similar activities also need the same inputs and have comparable by-products. The higher the network-diversity, the more diverse the waste-streams and input-needs within the network are. Without a high network diversity, it is difficult to find partners to setup mutual beneficial IS networks (Neves et al., 2019).

2.3.2 Economic conditions

Although many scholars mention economic reasons as the most prominent motive for self-organized IS, there are also several economic barriers described in literature that obstructs closing material loops and IS practices. First, it requires firms to change current practices, for instance by changing the infrastructure, train employees to work in a different way, or innovate production processes (Kazancoglu et al., 2020). This is often associated with *high investment costs*, which is particularly difficult to manage for SMEs because they tend to have less assets and have more difficulties obtaining funding than large corporates (De Jesus & Mendonça, 2018). The costs of closing loops are not limited to the initial investment of changed processes, it also generates operational costs for new activities. According to Mishra, Hopkinson, and Tidridge (2018), the costs of collecting, separating, storing, and transporting waste-streams forms one of the most important barriers for closed-loop supply chains. The supply-chain related barriers will be discussed later in this chapter. Besides, there is uncertainty about whether the initial investment will provide sufficient returns due to cost-reduction or new streams of income, for instance generated by the sales of by-products. These *investment and profitability risks* form a barrier of the adoption of IS (Geissdoerfer et al., 2017; Ritzén & Sandström, 2017). Both these risks and the economic motive to close material loops by IS and/or waste valuation are impacted by *low waste disposal costs* (Henriques et al., 2021; Kazancoglu et al., 2020). After all, if waste disposal is cheap, there is less economic incentive to reduce waste production and it makes it harder to justify investments needed to close material loops. A similar barrier arises in case of *low prices of virgin materials* (Neves et al., 2019). In some industries, for instance the textile industry, some recycled materials are still more expensive than virgin materials because of low economies of scale or technological immaturity (Kazancoglu et al., 2020).

2.3.3 Technological conditions

Technological immaturity can indirectly cause economic barriers for IS and closed-loop production. However, scholars have also identified several technological aspects that can form direct barriers. As explained in this chapter, closing loops and adopting industrial symbiosis require changes in the way organizations work. It may involve technological challenges in order to make by-products suitable to be used for different purposes, or to change manufacturing processes to enable raw input substitution. The technology and the knowledge needed to do this is not always present or available yet. As a result of a lacking *availability of technological innovation,* firms sometimes simply do not know how to close its loops in practice (De Jesus & Mendonça, 2018). The technology needed also entails methods to efficiently recover and separate by-products (Henriques et al., 2021). Overall, technological innovation is key to IS and closing loops. Another concern is the *lower material quality.* In particular when working with waste streams, since the quality of waste materials and by-products is often inconsistent and the composition can be complex (Domenech Aparisi, 2010; Henriques et al., 2021; Kazancoglu et al., 2020).

2.3.4 Policy conditions

Although policies and legislation forcing organizations to re-think their use of virgin materials and waste production are considered key for IS emergence (Chertow, 2007), *Obstructing or lacking legislations* can also refrain firms from doing this. In the context of closing material loops, existing environmental legislations impact what is considered a waste product, while there may still be innovative potential for reuse or value retention (De Jesus & Mendonça, 2018). Examples like low-landfill taxes, insufficient regulations, or a lack of education on IS are identified as unfavorable conditions for IS (Neves et al., 2019). *Bureaucratic procedures to obtain permits and certifications* form a more specific policy barrier, highlighted by several authors (Henriques et al., 2021; Kazancoglu et al., 2020; Kirchherr et al., 2018). In particular in the field of green supply chain management, certifications of resources are important since they provides certainty about whether recycled or reused materials comply with expected standards (Kazancoglu et al., 2020). However, if certification processes are inefficient and time consuming, firms will be less motivated to obtain the right paperwork necessary to foster material exchange.

2.3.5 Supply chain conditions

Closing material loops comes with several supply chain-specific difficulties. Rather than disposing by-products, firms need to arrange additional transport to move resources back and forth between much more actors, rather than receiving input materials from a fixed supplier and trashing all unnecessary by-products in as in a linear economy. This larger transport network, as well as reverse logistic practices to return materials like packaging increases *transportation complexity* (Hazen, Russo, Confente, & Pellathy, 2021; Mishra et al., 2018). For firms, this is more complicated to handle than its linear counterpart. Another important barrier is the *limited availability and planning of received materials* (Kazancoglu et al., 2020; Leder et al., 2020). In order to close material loops, firms have to connect their supply chains. This makes them highly dependent on each other's amounts of available by-products, as well as the moment these become available. Therefore, manufacturing processes need to be aligned carefully. This in contrast with a conventional buyer-supplier relationship in which the buyer can exactly request when to receive how much materials, enabling them to use just-in-time management. Not only the purchasing and receiving activities may form a barrier for IS, the process of *collection and separation* also impacts firms' logistical processes (Kazancoglu et al., 2020). Companies need to collect and store by-products and in order to maximize value retention, waste streams need to be as pure as possible, resulting in separation activities. All of which is not necessary in an open supply chain.

2.4 Preliminary conceptual model

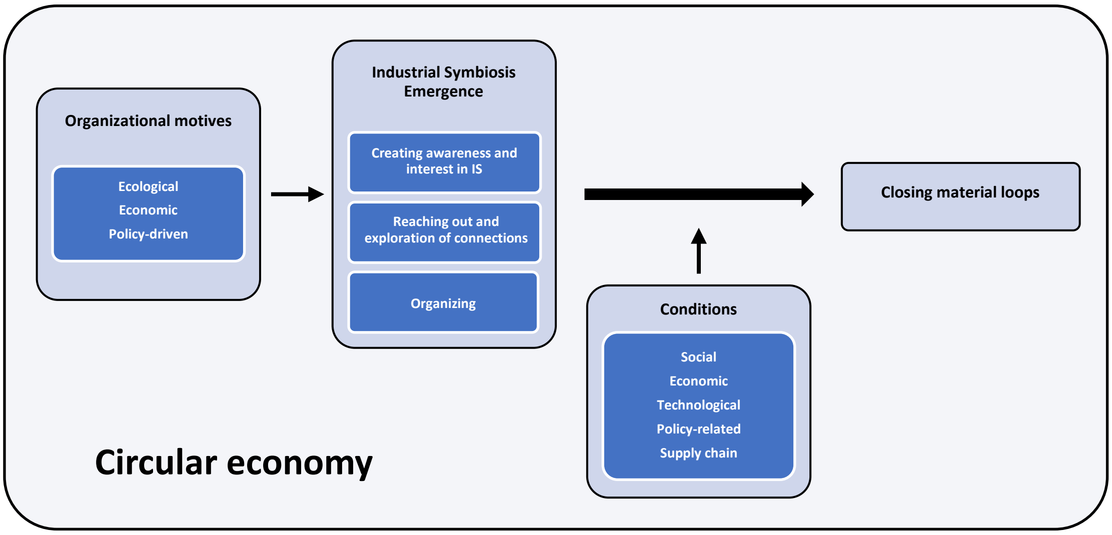


Figure 4: Preliminary conceptual model

Based on the literature study, the preliminary conceptual model in figure 4 has been constructed. The different types of organizational motives to engage in IS are expected to trigger the core IS emergence activities which are described in paragraph 2.2.3. However, reasons for companies to engage in IS are not expected to directly lead to closed-loop production. Scholars from different fields have described multiple contextual factors impacting IS realizations in practices. These factors are said to differ a lot, depending on the region and industry. Although the importance of taking into account contextual factors has made clear, how they exactly impact the IS emergence, and the actual establishment is uncertain. Therefore, the preliminary model visualizes the impact of conditions on the process from IS emergence to closing material loops. Which conditions are most important in the context of collaboratively closing loops, and how these factors impact the different emergence processes will be investigated in the empirical part of this study.

Chapter 3. Methodology

3.1 Research design

The goal of this research is to explore how Dutch microbreweries can convert their wastes into resources through IS in a CE. In the previous chapter, the importance of understanding intervening factors like motives and conditions on the emergence of IS is explained, and an overview of generic conditions are given based on a literature study. The empirical part of this study aims to provide in-depth knowledge about how and why these conditions affect the emergence of IS among Dutch microbreweries. Therefore, the literature study to identify conditions is followed by a qualitative approach with case studies to understand the breweries' perceptions and how they impact the emergence of IS to convert wastes into resources. A qualitive method is preferred over a quantitative method since it enables the researcher to not only identify perceived barriers, it also helps to obtain an understanding of the motivation of the actors involved in the study (Vennix, 2019). In addition, quantitative research would be more suitable for theory testing, based on hypothesizes. However, this is not applicable since there is insufficient knowledge about the relation between closing material loops and IS. This is explored in the context of Dutch microbreweries. A quantitative approach would be suitable however, to validate the outcomes of this qualitative study on a large scale and to compare the results with for instance similar firms in different countries. However, this is beyond the scope of this research. A case study is suitable when asking a 'how' question when the researcher cannot control the situation that is subject to the research (Yin, 1994). This is both the case, since the contextual conditions Dutch microbreweries face are too complex to replicate in an experimental setting. Furthermore, a case study enables the researcher to obtain in-depth knowledge about a social phenomenon in the participants natural context, making it possible to compare different cases (Bleijenbergh, 2015). This is important, since this research aims at identifying and understanding barriers that are applicable to Dutch Microbreweries, and providing sector-specific recommendations to overcome these barriers. Therefore, comparing cases is important to enhance the generalizability of the outcomes.

3.2 Conceptualization of dimensions and concepts

The dimensions and concepts based on the literature study are summarized in table 2. Given the choice for a template analysis, the dimensions are preliminary and will not be leading throughout the data collection. It is still important however to define the concepts that are expected to impact the adoption of IS amongst Dutch Microbreweries in the context of a circular economy. First, an *organizational motive* for circularity will be defined as: *"the reason a firm decides to engage in circular efforts"*. Consequently, *circular efforts* also need to be defined. As described in the previous chapter, the three core principles of the circular economy are: designing out negative externalities like waste and pollution, optimize product and materials use, and regenerate natural systems (Ellen MacArthur Foundation, 2013, 2015, 2019). Since one of the research questions is aimed at describing why Dutch microbreweries are motivated to make circular efforts, all activities that are related to the three core principles are considered circular efforts. These also entails exploring the feasibility of certain opportunities for circular production, regardless of the outcomes. This is important, because a motive to search for these opportunities precedes the process of assessing the feasibility, therefore providing more in-depth knowledge than solely focusing on the motives behind implemented circular practices. Since this study focusses on *closing material loops*, this also needs to be defined. In literature, 'closing loops' is often associated with Circular, Green, or Closed-loop Supply Chain Management (Hazen et al., 2021; Winkler, 2011). In some cases, literature focusses on the combination between reverse and forward supply chains (Strähle & Philipsen, 2017), which has to do with retrieving products or materials after being used by the customer. However, in beer production, it is not feasible to get back water and nutrients from the consumer after the actual consumption of beer. This would only work with packaging materials. However, in beer production, it is feasible to replace virgin inputs and prevent wasting by-products. Therefore, *closing loops* will be defined as: *"incorporating waste back into one or more stages of production"* (Davis et al., 2016, p. 12). This can be done on both the input as well as the output side of beer production, and can be done individually as well as collaboratively with other organizations. Finally, a *barrier* will be defined as: *"a factor that hinders or obstructs the development of symbiotic synergies"* and an *enabler* is *"a factor that facilitates and supports the concretization of symbiotic synergies"* (Henriques et al., 2021, p. 7) and a *condition* is a relevant aspect which can either enable or hinder the emergence of IS.

Concept	**Dimensions**	**Source**
Organizational motives for IS	Economic	(Chertow, 2007; Doménech & Davies, 2011; Mirata & Emtairah, 2005)
	Policy driven	(Chertow, 2007)
	Ecological	(Boons et al., 2017)

Dimension	**Conditions**	**Source**
Social	Trust	(Chertow, 2007; Neves et al., 2019)
	Willingness to cooperate	(Chertow, 2007; Neves et al., 2019)
	Knowledge about other firm's resources	(Chertow, 2007; Domenech Aparisi, 2010; Madsen et al., 2015)
	Short mental distance	(Domenech Aparisi, 2010; Kirchherr et al., 2018)
	Network diversity	(Neves et al., 2019)
Economic	Investment costs	(De Jesus & Mendonça, 2018; Mishra et al., 2018)
	Investment and profitability risks	(Geissdoerfer et al., 2017; Ritzén & Sandström, 2017)
	Waste disposal costs	(Henriques et al., 2021; Kazancoglu et al., 2020)
	Price of virgin materials	(Neves et al., 2019)
Technological	Availability of technological innovation	(De Jesus & Mendonça, 2018; Henriques et al., 2021)
	Lower material quality	(Domenech Aparisi, 2010; Henriques et al., 2021; Kazancoglu et al., 2020)
Policy	Obstructing or lacking legislations	(De Jesus & Mendonça, 2018; Neves et al., 2019)
	Bureaucratic procedures to obtain permits and certifications	(Henriques et al., 2021; Kazancoglu et al., 2020; Kirchherr et al., 2018)
Supply chain	Transportation complexity	(Hazen et al., 2021; Mishra et al., 2018)

	Limited availability and planning of received materials	(Kazancoglu et al., 2020; Leder et al., 2020)
	Collection and separation	(Kazancoglu et al., 2020)

Table 2: Concepts and dimensions based on literature research

3.3 Data collection

The data is gathered by conducting eight semi-structured interviews, in which the interview questions are based on the literature study of the previous chapter. Semi-structured interviews have the advantage of enabling the participants to add important aspects that they consider important for the topic which were initially not present in the interview script. This provides a more in-depth understanding of the relevant dimensions of the barriers for IS in their specific context (Bleijenbergh, 2015). Document analysis will be used as well. This enables the possibility of triangulation, which functions as a tool to reduce observer bias and enhances the quality of the data (Vennix, 2019). The interview questions are based on five preliminary dimensions and barrier themes that that are explained in the literature study in the previous chapter. However, these dimensions only function as a baseline to structure the interviews. The final barriers and dimensions are based on the research data. Six out of eight interviews were held in-person, since this enables the researcher to make better observations of non-verbal communications. Besides, being able to visit the brewery of the informants gives a better understanding of the context in which the company operates. For practical reasons, two interviews were held via Zoom. In both cases, the geographical distance between the organization and the researcher were severe, and one participant had limited time available due to a busy schedule. All interviews were recorded after approval from the informants to enhance transcript quality. Lastly, all interviews were based on a general interview protocol, enabling a consistent introduction of the topic and to make sure all of the predefined questions were being asked. The main reason for this is to enhance the repeatability, and in turn the reliability of the data collection through semi-structured interviews (Bleijenbergh, 2015). Another advantage of semi-structured interviews is the possibility to ask, follow-up questions based on the response of the participants to clarify their thoughts. Given the small number of interviews and cases, case-studies often have a limited reliability. However, in qualitative research, controllability is often considered more important than reliability (Bleijenbergh, 2015). This can be achieved by providing clear justifications of the choices made by the researcher. The external validity – which indicates the generalizability of the study – is also limited in case of qualitative research, compared to a qualitative approach. In-detail results of this study method will not be generalizable outside the observed cases. However, patterns and trends in the data can still be valuable (Bleijenbergh, 2015). Therefore, this research can still be of value for other Dutch microbreweries in the Netherlands. The interview protocol can be found in appendix 1.

3.4 Case selection

This research focusses on Dutch Microbreweries, defined as: *an independent brewery (not owned by or under supervision of another manufacturer of alcoholic beverages), with an annual production below 1,8 million HL, using its own brewing facilities.* Consequently, cases are selected on: production volume, own brewing facilities, and independence. This independence is important since a brewery that rents external production facilities cannot fully control the manufacturing process and is likely to rely on the choices made by the company that facilitates the production. Informants are selected purposeful rather than random, making sure that all interviews provide rich data while maintaining research efficiency (Palinkas et al., 2015). All informants are selected based on their involvement in management and sustainability decisions. This is important because decision makers can provide the most in-depth insights in which conditions microbreweries face and how they are experienced. In addition, breweries are selected based on information about circular involvement on their websites and in external articles to make sure these breweries have at least a certain affinity with ecological sustainability. For this study, eight cases are selected. Ideally, each case would have consisted of multiple interviews to increase the validity of the data. However, due to the focus on microbreweries, the companies are small and mostly have less than five employees. Therefore, the owner or manager most responsible for sustainability related issues is interviewed, resulting in eight interviews. All cases are initially contacted by phone or e-mail to introduce the research objective and to ask if the brewery is willing to participate in this study. All interviews are conducted in the informants' native language (Dutch) to prevent language barriers.

Finally, it is important to stretch out that only a minority of Dutch microbreweries publicly communicate circular or sustainability interests. When combined with the other selection criteria, only a small number of potential cases are suitable for this study. In addition, some cases have very specific characteristics. Therefore, no extensive case descriptions will be given to respect the anonymity of the informants. However, a brief overview can be found in table 3. The eight cases are located in five different provinces.

	Production* (hl)	Turnover* (€)	Role informant	Via	Duration
A	1200*; 2000**	500k*	Co-owner	F2F	105 min
B	550*	n/a	Co-owner	Zoom	70 min
C	200*	60k*	Co-owner	F2F	120 min
D	500**	200k**	Co-owner	F2F	90 min
E	300	100k**	Co-founder	F2F	70 min
F	1200*; 2500**	750k**	Brand manager	Zoom	80 min
G	450**	450k**	Director	F2F	60 min
H	400	1,21M	Owner	F2F	45 min

*Table 3: case overview; *2020 is severely impacted by COVID-19 measures, **based on 2021 target*

3.5 Data analysis

The literature study provided a general understanding of dimensions and conditions impacting IS emergence, but there is insufficient knowledge about how this works in the context of closing material loops, specifically in the Dutch microbrewery industry. Therefore, a full deductive data analysis is unsuitable for this study since it would limit the data interpretation to the predetermined dimensions. In contrast, a bottom-up approach, or inductive reasoning would be more suitable if there is very limited understanding of underlying themes within the research topic (N. King, Brooks, & Tabari, 2018). The latter is not the case, given the large number of publications about conditions of CE and IS practices. Instead, the data analysis will be conducted based on template analysis, which can be placed in between inductive and deductive reasoning. The advantage of a template analysis is that it provides more flexibility in the coding structure, enabling the researcher to tailor the coding process to the research objective (N. King et al., 2018). Based on the recordings, all interviews are transcribed verbatim. The recordings are imported in Atlas.ti software to facilitate the coding process.

For the data analysis, the sequential steps as described by N. King et al. (2018) are followed. Before defining a coding template, it is important the researcher gets familiarized with the data. Since all interviews are held and transcribed by the individual researcher, this was already the case. In addition, all interviews are read again before coding. Next, several *a priori* themes are added during the preliminary coding phase when parts of the data appeared to match the concepts and dimensions as described in table 1. It is important to note that these *a priori* themes only functioned as a guidance and remained subject to change during the analysis. After an initial coding round of the first three interviews, the clustering phase started in which similar coding's were clustered and arranged over several levels, resulting in the initial template. Hereafter, this template is used to code the remaining transcripts and is revised when necessary to maintain fit with the data. This resulted in 3 alternations before reaching the final template. The process of the template analysis, including the final template and coding scheme can be found in appendix 2. To prevent the loss of context due to accumulated translation limitations, the entire process is conducted in Dutch and the translation is done afterwards.

3.6 Research ethics

It is important to be aware of the researches impact on the participants, and to handle data with care. Diener and Crandall (1978) summarized four ethical core principles within management research: in ethical research, participants experience no harm; there is no lack of informed consent; privacy is not invaded; and there is no deception, referring to presenting the research as something it is not. To meet these principles, several actions are undertaken. First, participants received an overview, providing a description of the purpose of this research as well as an overview of the conditions of participation with the explicit notion that participation is voluntary and date is exclusively used for the purpose of this research. Second, interviews are anonymized from the moment of transcription, and both names and transcripts remain confidential and are not shared with others. Third, transcripts are solely stored locally, to prevent cloud data leaks, and will be deleted after the final grading of this project. The transcripts are sent to the participants for approval or revision before the analysis, and all participants are informed they can opt out until they approved the transcript and gave permission to use it for this study.

Chapter 4. Findings

In this chapter, the findings of the data analysis will be described in four sections. First, the circular efforts of the breweries will be described. Second, the reason why the breweries have done these efforts will be assessed. Third, an in-depth explanation of the most important conditions that impact the degree in which breweries are able and willing to collaboratively close their material loops will be given. Finally, these conditions will be linked to the three crucial organizational activities of IS emergence as described by Mortensen and Kørnøv (2019).

4.1 Circular efforts in the beer industry

All eight breweries that are part of this research have conducted circular efforts in some degree. Sometimes individually, for instance optimizing the brewing process to reduce energy and ingredient use, but also in a collaborative way, like sharing by-products with others. In this paragraph, the question which circular efforts Dutch microbreweries have made will be answered. A simplified overview of the IS activities leading to waste valuation can be found in figure 5 and appendix 3.

4.1.1 Less use of water and energy

Brewing requires large amounts of water since it is not only used as an ingredient, but also for cooling and cleaning purposes during the production. Early in the process, hot water is necessary, while cold water is needed to rapidly cool down the boiled wort to the fermentation temperature. Some breweries, like case C and E, directly reuse warm water for cleaning purposes after cooling, rather than putting it down the drain and re-heat fresh water. Others have more advanced technical solutions: *"In the brewery, we have a system which recovers water after brewing (...) part of this water can be re-used for activities like cleaning, but condensed water cannot be re-used because it can be contaminated, but we still use this for cooling and reheating." (case F).* When there is no better purpose possible anymore, this brewery uses it to flush the toilets. These efforts to recycle water for less demanding purposes decrease water use. One brewery even formed a collaboration with a waste revaluation company to look for more advanced possibilities of water reuse: *"We have a collaboration with an organization [name company] (...) and what they do is capturing waste streams and see if they can still use this, and if so: they will. There is a container on the site which houses a laboratory and they do our waste-water. (...) So when we sip – clean and empty – a tank, we recapture this and then they receive like 100 liters of this, and 100 liters of that and they analyze this for half a year to see what they can grow in it and what they can still extract from it." (Case A)*. This enables components of the waste water to be separated and used for other purposes. Three breweries pointed out they would like to filter their wastewater before draining, for instance to filter out cleaning products but this is not being done yet due to practical, policy or economic challenges. These will be explained in conditions section.

Recapturing and storing hot water in a boiler system also reduces energy use by recovering heat surpluses. Another example of an energy reduction effort can be found in case F, which joined a pilot with an insulation company to further reduce the energy use of an already highly efficient cooling system by insulating all pipes. Most breweries prefer the use of energy over gas for environmental reasons: *"This brewery was equipped with a large gas-powered steam generator. A huge machine, bigger than the brewhouse because we have quite some capacity here. Such a gas pipe, and such emissions you know… It didn't feel right. (…) Therefore, we got rid of it and purchased a top of the bill electric steam boiler." (case A).* Not only the brewery itself, but also the fork truck and van of this brewery are powered by green electricity. Case G joined a local initiative which will build a nearby solar park and five windmills, and another brewery went an extra mile with its renewable energy efforts resulting in another challenge: *"Apart from the – I will call it the central heater for brew water – this building is gas-free. So the entire buildings infrastructure is free of gas and we generate so much energy that the local operator disconnected us from the grid for a while because they couldn't handle it." (Case B).* The efforts show that reduction of energy and water usage is common in the cases investigated. The symbiotic exchange of wastewater currently only takes place on a small scale in case A and the exchange of electricity surpluses from solar panels only take place by delivering it back to the grid. However, this electricity is not an actual waste-stream of the beer production process.

4.1.2 Grains

Water and grains are the main ingredients of beer. All breweries within this study purchase their grains. However, several efforts have been made to reduce the environmental impact of raw grain products and to retain value by recirculating grain remainders in symbiotic collaborations. When looking at the input-side, purchasing biological, and preferably local malts is common. The definition of local differs per brewery: *"Sometimes, you hear they have malts from Russia which are really cheap. Ok, but I think it's all so fuzzy. Why does it have to come from such distances (…) I buy from the Netherlands and Belgium (…). From one of my suppliers, I know they also have German malts, but apart from that, they sell Dutch and Belgian malts." (case A).* In contrast, case C, D, F, and G obtain its grains from farmers within the province or local region, sometimes at walking distance from the brewery. These grains are often biological, and grown in a sustainable and regenerative way: *"No monoculture, not heavily sprayed, not over-fertilized. So not an almost-dead 2,5 meters tall corn field, but a very much alive, colorful field of grains where insects are living. A large diversity of insects, but also the tiny crawlers and rodents that are being preyed on by birds and owls. Just a huge biodiversity." (case D)*. This contributes to the third principle of circularity: regenerate natural systems. Case E exclusively focusses on the constant quality and technical characteristics of the malts, and is not concerned with its environmental impact.

Two breweries (A and D) invested in an expensive filter system to significantly increase its brewhouse efficiency, reducing the grain needs by 20-30%. This also affects the total supply chain: *"It all comes* *together. When you need less input, you also need to transport less and you reduce the energy use, for instance in the malt house. (...) The entire chain needs less mass for the same amount of beer. The same applies to your wastes. You have less waste. Besides, the waste is much dryer so the entire mass of waste and also the transport mass is much lower." (case D).*

At the output side, spent grains are the primary byproduct of the brewing process. None of the breweries waste the spent grains after brewing. Most of them donate this by-product to local farmers to feed their livestock, since it still contains high amounts of nutrients like proteins and fibers. Sometimes, the livestock is linked back to the restaurant of a brewery: *"We deliver the spent grains to a petting zoo and it is being used as fodder. To make it more circular, the livestock is being slaughtered after having had a good life. Then meat and sausages are produced, and this meat is used for the BBQ-arrangement and the sausage is on the menu as a snack." (case E).* Case D is part of a larger symbiotic network. It not only buys dairy from the farm that receives the spent grains, but the locally grown malts they use for their beers are also fertilized by the manure of the same cows that are fed the spent grains. Several breweries have made efforts to collaboratively develop food products containing spent grains for human consumption, which are sometimes sold at the same breweries' bar or restaurant. Bread is mentioned most frequently, other examples are: cookies, fried snacks, and crackers (not in production yet). Case C managed to set up IS with a bakery store: *"And then the loop is closed, because you use bread leftovers in the beer to substitute grains, and the [spent] grains go back to the bakery who uses it to bake bread or cookies. And we also have shared customers. In a hotel, the bread containing spent grains [from the brewery] is eaten in the morning, and in the evening, they are drinking beer containing bread leftovers." (case C).* As a result, over 50% of their produced beers contain bread leftovers. Other breweries (A and G) gave it a try but decided not to do it again, the reasons will be explained in the conditions section. Spent grains can also be used for non-food purposes: case F exchanges grain remainders with a company who manufactures "beer paper", and uses it for its menus. Finally, case G pointed out a company tried to develop spent-grain based insulation panels for buildings but it did not lead to an actual product.

4.1.3 Yeast

Most breweries use yeast cultures multiple times since it is relatively easy to cultivate and grow yeast from an original strain they purchase. However, over time the risk of contamination with external and unwanted yeast-strains increases, limiting the potential number of reuse-cycles. One brewery is specialized in wild fermentation – a traditional way of brewing in which multiple wild yeast strains are used rather than one specific "clean" strain – and reuses its own yeast cultures time after time since the 'contamination' with wild yeasts characterizes this specific beer type. The reuse of yeast-residue after (initial) fermentation barely happens. It is mostly flushed down the drain. Brewery G has been contacted by a startup company who wanted to extract proteins from yeast remains and convert them into meat substitutes but in the end, the company got funded in such a degree that they had to focus on bigger breweries. Breweries D and G are also aware of the technological possibility to use yeast residues for human consumption, but acknowledged these processes require large scale, highly complex industrial activities which are not a viable option for a small brewery. Despite it contains nutrients like proteins, yeast is not being exchanged to be used as an input for human food production because the cases in this study cannot find a suitable partner to set up this IS. The barriers that hinder the emergence of this potential IS primarily have to do with logistical challenges like low waste volumes, making it very difficult to find a suitable (commercial) partner. More explanation will be given in the conditions section.

4.1.4 Hops

Several specific (aroma) hop types cannot grow locally due to the climate, and are farmed in the United States. Most breweries purchase these hops from wholesalers. However, most breweries try to use as much European or sometimes even domestic hops as possible to reduce the ecological impact of transport: *Many brewers are proud they use really nice American west-coast hops. Well, they are quite exceptional. They originate from a really nice Indians tribe from the west coast, but I would like to get it from somewhere closer. (case B)*. Only one brewery (case G) only uses domestic hops from nearby growers, this brewery has a strong focus on local ingredients in general and aims at purchasing ingredients that are produced within a 50 km radius for sustainable reasons. The main reason Dutch hops are not frequently used has to do with taste characteristics: they are not suitable for every beer style. Nevertheless, some breweries grow (case C and D) or used to grow (case F) their own hops: *"We have 80 hop plants and if you look at the yields – and we've had good yields last year, and this year is alright – then it's around 1/10th or less of the amount we need to brew an entire year. Therefore, we cannot use it as a major source for our hops, so our main goal with the hop garden is to show the process and that it's possible (...) but it does not replace a significant share of what you normally would have purchased." (case C).* Hop residuals are given to waste processors (case G) or farmers (case F) and dissolved hops are flushed down the drain together with the yeast remains (case H and A). The waste-processors use the green wastes to make compost. As explained in the *water and energy*-section, brewery A also gives samples of its wastewater to a company for further analysis for potential reuse.

4.1.5 Additional ingredients

Besides bread, some breweries (C and G) make additional collaborative efforts to prevent other eatable resources from being wasted: *"Yes, sometimes leftover fruit, like cherries but also things like plums that are leftovers for instance. We work with biological farmers a lot, and there have been moments that there were many worms in the plums. He cannot sell this on the market anymore, but is still fine to process in beer. Same with cherries. If they are damaged by hail…." (case G)*. Breweries B, C, and G also pick herbs and seasonings that are grow naturally around the brewery so they do not have to buy them, limiting transportation and unnecessary farming activities.

4.1.6 Beer leftovers

During the filling or labeling process, some bottles or cans do not match the quality norms for selling. In these cases, the beer is often converted to or used in different products. For instance, beer containing products that are produced in collaboration with other partners like beer mustard or beer sausages (case F) or it is distilled into liquor (case C, F, E) or freeze-distilled into an Eisbock beer (case C). The same applies to lower part of the beer tanks after fermentation when the yeast and hop sediments are being drained. Besides commercial distilleries, private persons can also be very willing to receive this: *"We also have this yeast sediment. (…) We are doing trials with someone we know who has a distillery in his basement and he wants to turn it into whiskey. So from the sediment that is usually wasted. I've tried it recently and it tasted really nice, haha."(case E).*

4.1.7 Packaging

The packaging in which the beer is being sold is by far the largest packaging-stream of all breweries. Other packaging materials are for instance grain bags and pallets. All cases make efforts to reduce the impact of beer packaging, although the degree in which they do varies per case. There are two types of kegs: plastic disposable, or metal reusable kegs. Plastic kegs can be recycled, but they cannot be re-used for the same purpose while metal kegs can be used many times before the metal is recycled again. Three cases already exclusively work with metal kegs (case A, D, F), and a fourth brewery has started a transition (case B). This does not only require an investment in kegs (they remain property of the brewery), but also in logistics, a keg cleaner and the time to clean them. During the interview it turned out that one brewery (case D) makes its keg cleaner available to another small brewery against a symbolic charge for the water and energy expenses to enable them to use metal kegs as well. Breweries using plastic kegs also made efforts to reduce its impact if they are the end user: one brewery (case C) donates them to artists in a local cultural hub, which are turned into light strings for festivals, another brewery joined a recycling program: *"And [name company] is the manufacturer of the kegs and they setup a program with [name company] (…). So when you gathered 100 of those things, you have a big bag and they collect hem for free. People with a distance from the labor market pull them apart and new kegs are being made. We also participate in this." (case E).* In terms of small packaging, disposable bottles are most dominantly used. Deposit bottles are coordinated by the *Nederlandse Brouwers* organization, which can only be joined by large breweries. Therefore, the breweries within this study have no access to deposit bottles. However, one brewery is partially bypassing this issue by setting up a partnership with another organization, reducing its glass waste by inserting virgin reusable bottles in the deposit loop rather than buying disposable glass which is wasted for sure: *"Yes, so we made an agreement like: ok, we start buying those Dutch, brown deposit bottles. We borrow crates from this partner and all bottles that are returned to us are going back in crates to this wholesaler in [city]." (case D).* One brewery only uses cans (case A) for environmental and quality reasons: *"Two cans piled* *up use the same volume as a bottle. A can has barely any weight, is faster to chill. You put in in the fridge and it's instantly cold. You don't have to chill all the glass. It's also better sealed compared to a bottle, it is not translucent, and it's easier to recycle." (case A).* One brewery (case H) focuses on local sales only, and only offers simplistic 1 liter PET bottles which are filled on the spot, since they want to reduce packaging and transportation waste and figured out these bottles have a significantly lower environmental impact compared to bottles. These bottles can be recycled together with other general plastic waste. Furthermore, waste streams are mostly separated, and if possible, packaging materials are reused or given to another actor for new purposes. Case E for instance, gives containers for chemicals to a nearby farmer who reuses them, and case C gives wooden pallets to a nearby cultural hub to repurpose them by converting them into furniture.

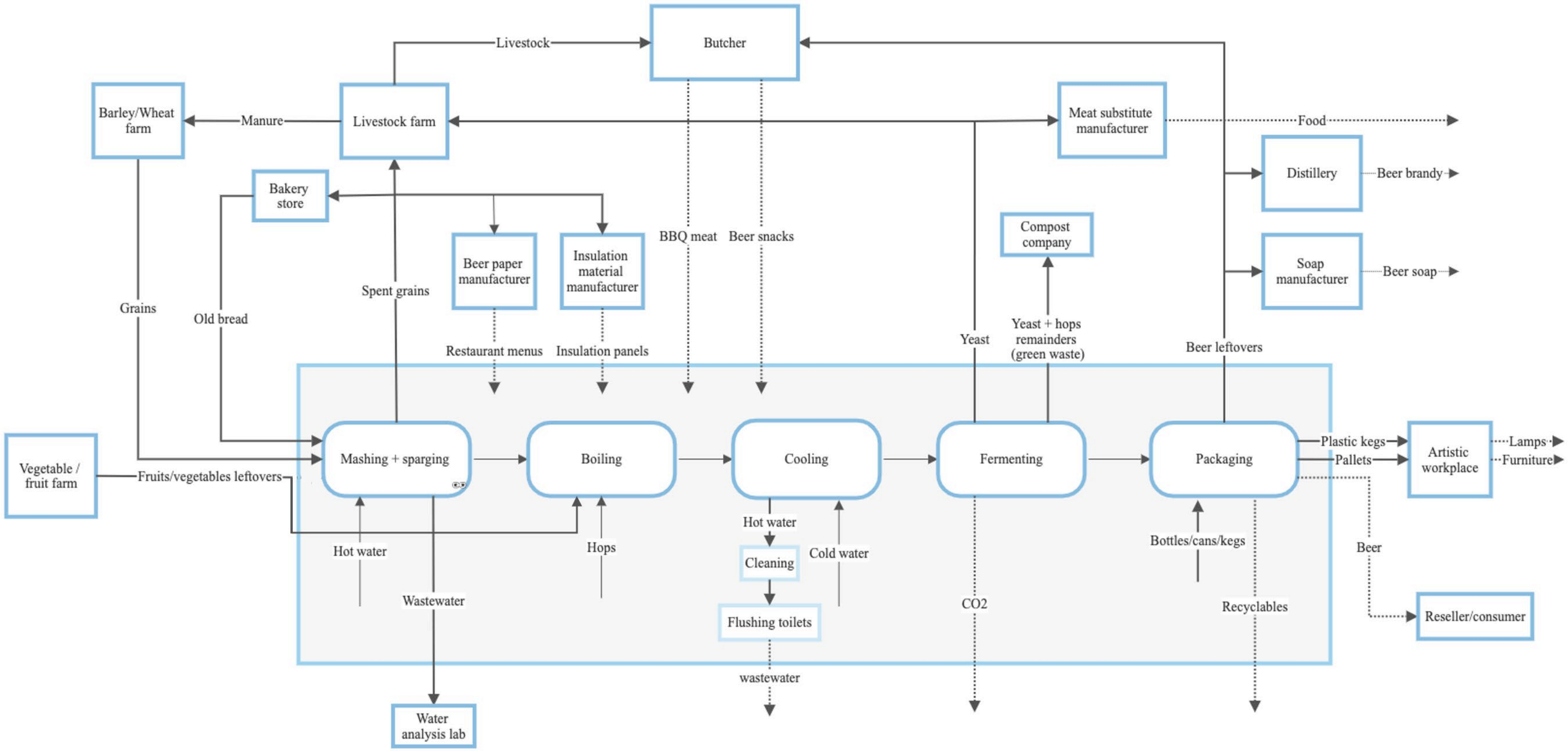


Figure 5: A simplified overview of IS examples based on the results

4.2 Motives for Circular practices

All cases have made circular efforts to some degree. In this paragraph, the question what the microbreweries in this case motivated to make circular practices will be answered. The motives are divided over four dimensions: ecological, economic, social, and policy-related. An overview can be found in figure 6.

4.2.1 Ecological motives

The ecological motive appeared most dominant in the selected cases. Seven cases consider ecological sustainability a norm: *"In particular, I see circularity as something that should be self-evident, rather than a marketing gimmick, but in too many cases it is a matter of: 'look at us, being sustainable' (...) We all want to contribute and make sure the children of the future can also live in a nice world. So why would you even consider things that are not fundamentally sustainable?" (Case F).* The ecological motives are often based on the owner or managers' personal norms and values and are reflected in the business activities: *"Things like these [doing the right thing, like preventing waste and critically assessing the origins of resources] are part of our DNA, so they are also part of the companies DNA." (Case H).* Examples like these show the ecological focus is deeply embedded in the organizational identity of the cases. The ecological motives are twofold. First, lowering the environmental impact of business activities. Second, boosting value retention of resources.

<u>Lowering the environmental impact of business activities</u>

Most brewers explicitly mentioned they find it crucial to lower their environmental impact. This is fostered by the idea that humans are rapidly exploiting the planet resources: *"Well, there is no reason not to be circular (...), it should always have been the case. I mean, the previous generation and my generation have neglected it. We all know the numbers, we are exhausting every… every year, the day we've already finished the commons for that same year is approaching earlier in the settlement with our planet. And this has to get back in balance as fast as possible." (case B).* The motive to lower the environmental impact also fostered by overall pollution and climate change: *"We have to act; you can see what's happening in the world yourself. Last year: storms, disasters, and overall misery. It is madness, right? We are already too late but still…" (case A).* In addition, one brewery has such a strong focus on sustainable food production that it is reflected by its main goal: *"Basically, the most important goal: we want to make a difference in the food transition. We realize the way food is currently produced can't last much longer. It is unsustainable. It is bad for our health, as well as for the planet, so we want to contribute to a change." (Case G).* Although different reasons are mentioned during the interviews, the breweries in this study thrive to minimalize the negative ecological effects of their activities and ideally make positive contributions instead.

Boosting resource value retention

All breweries unanimously mentioned they consider it a shame to waste resources that still have potential for further use. Therefore, they seek for IS opportunities to maximize value retention of resources: *"I pay a premium for this [name composter company], it costs money to do this. Throwing it away with the residual waste is probably cheaper but we specifically do this because it's important for us. So, I prefer those kinds of collaborations to prevent our raw materials from being wasted." (Case G)*. Every brewery shares spent grain with nearby farmers to feed livestock. Some breweries are motivated to go the extra mile and seek for collaborative opportunities which are on a higher circular order: *"From an energetic perspective, it's composting and it returns to the soil. I don't know what burning would yield. You could also consider it biomass, convert it to methane with a bio fermentation system and burn it. It is possible, but those are all fairly low levels in the energy hierarchy. In contrast, it currently remains within a cycle for human food. For us, the highest attainable situation would be when you manage to keep it within this cyle completely, so it flows from one human edible to another." (case D)*. This is in line with brewery G, explaining they would prefer sharing spent grains with a partner who processes it in insulation material for long-term use. Overall, it points out the desire of brewers to increase or maximize value retention of its waste-streams motivates them to seek for IS opportunities.

4.2.2 Economic motives

Reducing costs

Only one brewery mentioned cost-reduction and increased efficiency as the primary reasons to make circular efforts: *"And that's what I like the most: being more sustainable is also about reducing costs. Many people are boasting that they do this for the environment. For some this might be the case. Well, I can tell you: I don't care about the environment. This is my personal opinion by the way, not the breweries'. However, if you use less energy and water, it also reduces costs and time and it affects the efficiency. (case E).* For other breweries cost reduction is not the primary reason, but it does motivate them to rethink the way they operate, both on the process or input side, as well as the output side. Optimizing energy and material use reduces operational costs. At the same time, giving away by-products rather than wasting it also provides financial savings: *"When we were unable to get rid of the spent grains for a while, we had to order additional green waste containers. And we thought… We are wasting a really nice product and we have to pay big money for this. That does make you more creative." (case B)*. However, the majority of the breweries were willing to invest additional time, effort, or money in some degree if this would make operations more sustainable. This will be further explained in the economic conditions section.

New market opportunities

Waste-to-resource activities can generate new product opportunities like beer-based liquor made from beer leftovers. Consequently, these products can be sold by the brewery to generate additional revenues: *"But I believe when you can develop a product that's feasible and not too complex to make and also possible to sell commercially, it can actually generate a revenue stream rather than wasting it or give it to livestock." (case C).* The other way around, they produce beer containing bread, beetroot and carrots, resulting in product differentiation thanks to someone else's waste-streams. Different breweries mention several examples, ranging from mustard and cheese to fried snacks and vinegar, all containing beer or by-products like spent grains. Sharing waste streams with other companies also generates new sales channels. Generally, when organizations are exchanging waste streams, they often also sell each other's products. Finally, a frequently mentioned opportunity of closing loops by collaborations is improving the company's story, indirectly leading to economic advantages. This differs from greenwashing: *"Not as long as it's authentic. But it would be if it's only a marketing story. This is much more connected to your fundamental believes. And as I said: I don't have to make profit on this. But yes, it helps creating fans, ambassadors through the authenticity of the story." (case F).*

4.2.3 Social motives

Reinforcing the region

Almost every informant pointed out to consider it important to support other companies within the region, and sharing by-products or co-creating more circular products with local businesses is a way to do this. Although reinforcing the region could potentially deliver joined economic benefits as well, the intrinsic drive to help local entrepreneurs out was emphasized in multiple cases, hence the social aspect of these practices: *"But this is fun. It's an example of both a local or regional business, and it's cross-pollination of collaborative entrepreneurship. (...) We support them, and they support us. And this is not just to get rid of our wastes." (Case E).* Besides, when sharing waste-streams, none of the breweries received any compensation in a monetary form. Informant F stretched out the importance of sticking with your own value proposition, rather than trying to make additional profits on activities where value is added by a partner, in order to keep collaborations successful.

Tracking and preventing societal harm of business activities

One brewery uses short supply chains and local partnerships, for instance with a nearby regenerative farmer, for another social reason: *"When we keep everything local, we can personally observe what happens. If you get it from elsewhere, you can't. For instance, when you buy clothing from Bangladesh, you can't see the people but it's still an aspect of sales. If they end up being buried under a collapsed building, it only becomes apparent afterwards. (...) The same applies to certain emissions and waste dumping in countries like China. Over here, it's not allowed and you cannot just do it. Besides, you* *would see it yourself. This whole social aspect is also really important in the end." (Case D)*. Therefore, becoming part of a circular network can also be driven by the desire to be able to track the societal impact caused by the activities of the brewery, providing the opportunity to prevent negative societal consequences.

4.2.4 Policy-related motives

Only one brewery mentioned an example of policy that could potentially be a motivation to reduce waste volumes: *"Yes, it's a pollution-tax, and there is the Water Authority fee. We are subject to the higher category of gastronomy and we have the brewery. For instance, for every 1000 liters of water you use, they assume you waste a specific amount. So the amount that's converted into beer is not wasted of course, so we can deduct this from the total amount. But we have a factor, for instance 8, so we have to multiply this fee by 8. If you can prove you have a water filtering system and you waste less, it may make a 50 percent difference." (case H)*. Apart from this single example, breweries point out there are several legislations to stimulate sustainable practices, but these do not apply to small breweries like them. Therefore, policy is not considered a motive for circularity. In contrast, policies are said to discourage circularity and IS. This will be further explained in the conditions section.

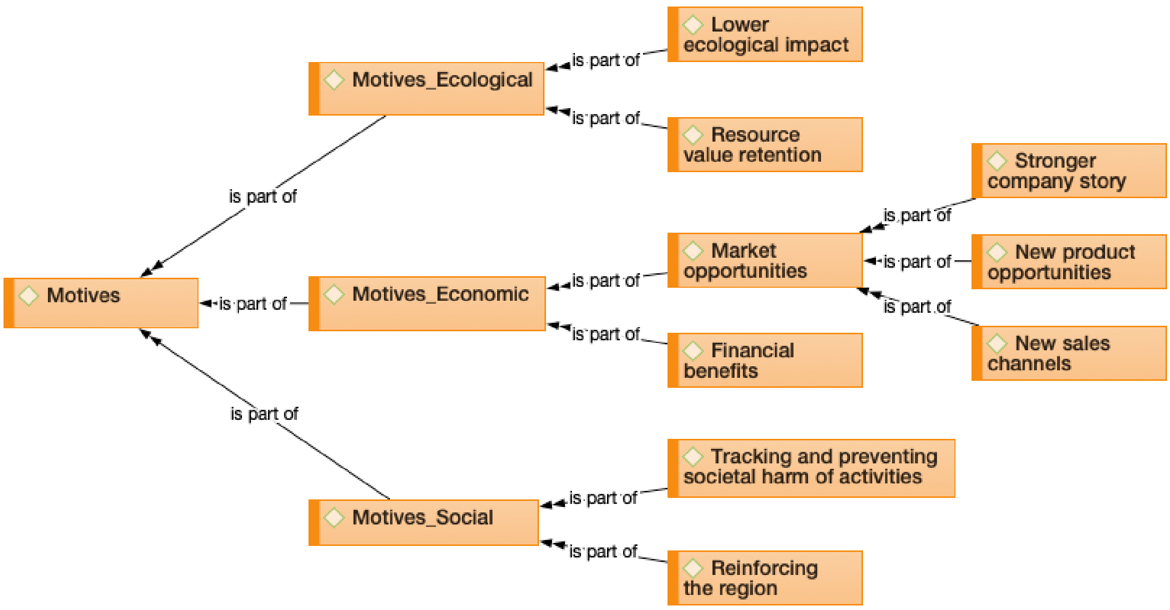


Figure 6: Motives for circular practices

4.3 Conditions influencing closing material loops through IS

In the previous section, both the efforts as well as the motives for breweries to engage in circular practices are explained. Some of these efforts are examples of IS. However, symbiotic practices do not emerge out of the blue, they are influenced by several different conditions. The conditions that are of importance for the investigated microbreweries will be described in this paragraph, answering the third sub-question of this research. The conditions can be divided in the five dimensions explained in chapter 2: social, economic, technological, policy-related, and supply chain. An overview of all propositions related to the conditions can be found in table 4.

4.3.1 Social conditions IS

Willingness to cooperate

When specifically asking about the willingness and importance of collaborations, all informants unanimously consider collaboration with other actors of great importance, this matches the social motive to support local businesses. One informant (case B) goes the extra mile and calls his Commercial Partnership (VOF in Dutch) a "*Vriendschap Onder Firma*", a Friend-based Partnership and use this as his business philosophy: *"To celebrate live, you should aim for joined entrepreneurship. This applies to friends, but also for people in a local community like a village, island, or a city. Therefore, we have the goal to collaborate as much as possible and create beautiful things together." (Case B).*

Proposition[1]: The high willingness of breweries to cooperate with other actors contributes to the emergence of IS.

Short mental distance

Breweries made clear they want their partner to think alike, since sharing by-products and closing loops creates a certain connection between the firms. For instance, in terms of: goals, ethical standards, and the overall way of conducting business. If this is not the case, IS is not likely to happen: *"every now and then we get in touch with people of whom you immediately notice they just want to make money, I can't stand this." (case H)*. None of the brewery's measure this in a systematic way, they conversate with other companies and are willing to give it a try when everything feels right. Some breweries prefer a connection which goes beyond resource exchanges: *"In the end, it is not only about economic gains and using by-products with a sustainable purpose. It is also about being able to use it as a means to share your story and identity. This is what we do, this is how we do it, and these are the partners we work with. Therefore, you also want a partner who is willing to be part of it and tell the story." (Case C).*

Proposition[2]: Conflicting goals and visions between actors hinder IS emergence.

Proposition[3]: Richness of collaborations contributes to IS emergence.

Trust

Incorporate others' wastes in products creates a dependency in business activities. Results show informants tend to keep faith in the good in people and strongly prefer trust-based informal agreements over contracts: *"The spent grains are based on trust. In general, we rely on trust if possible. Okay, the collaboration with this waste-processor is quite formal and therefore based on a contract, which is not complicated. If possible, we just make [informal] agreements when necessary, but when there is no need, we won't do this [and therefore rely on trust]." (Case G)*. Although it incidentally happens that agreements are not being fulfilled, it mostly works fine in practice. Setting up formal arrangements is considered a hassle and several brewers indicated they want to keep processes simple. One brewery pointed out a lack of trust from other actors sometimes hinders the formation of IS: *"We discovered there is a lot of suspicion among bakery stores about people who want to obtain their bread. (...) Apparently, some people ask for free leftovers, which they end up selling commercially. Several bakery stores experienced this, and as a result they were not keen on donating leftovers to others." (Case C).* IS requires companies to share internal knowledge and information related to circular opportunities or material flows. None of the cases considers this risky. Most were very willing to share knowledge to help competitors to become more circular and improve the sector as a whole.

Proposition[4]: Informal, trust-based agreements rather than contracts facilitate IS emergence.

Proposition[5]: A lack of trust in the receivers' intentional use of resources hinders IS emergence.

Network diversity

Closing loops through IS requires finding the right partners. Every brewery managed to find a partner to share its spent grains with. However, it often required active efforts to contact potential partners they did not know before, and many opportunities for reuse are more complex or less obvious. Several brewers (A, C, F) made clear they sometimes feel restricted in their network diversity: *'Especially the yeast [residues] should be used in a better way because it has such a high nutritional value. But the thing is, I don't know anyone who does this." (Case G)*. Although personal networks can be limiting IS, becoming part of local communities is mentioned to be an effective way to facilitate symbiotic opportunities. Case C for instance, used the cultural hub they are part of to find alternative uses for their wood and disposable kegs, and obtains large network opportunities due to a large local environmental festivity. Case D gained significant network advantage by entering a local association: *"It turned into an association but it started as a project founded by the municipality. Together with other production companies and retailers, we are really active within this association to stimulate and support each other and promote products so it also acts as a marketing tool. (...) You have to be able to tell people that story [about collaborative, sustainable efforts] and you meet those people in such associations. The province and municipality put quite a lot of effort in creating things like network events." (Case D).*

Proposition[6]: A lack of network diversity hinders IS emergence.

Proposition[7]: Entering existing local communities facilitates IS emergence.

External interest in IS

Four breweries experienced a lack of external interest in closing loops through IS as a barrier: *"The problem is – how can I put it nicely? – the local bakery store has limited interest in these innovations. If not, we would have been using it in bread already." (Case B).* Brewery H explained to be very willing to collaborate with educational institutions but they also turned out not interested. Brewery C managed to setup multiple IS collaborations, but points out it often takes a lot of effort to convince other actors of the benefits: *"People often consider it a disruption of their processes or workflow. To change this and be able to put your heads together, you really need people who like to experiment or think out of the box and willing to give it a go. (...) You try to convince them of the use of it, and the potential commercial advantages. In the end, people have to realize it themselves. If they don't see the point, it becomes very challenging." (Case C).* Besides low interest at local actors, two informants also mentioned dedicated waste-valuation initiatives aimed at breweries are lacking: *"Indeed, the challenge I face is there are insufficient initiatives that are focused on waste streams of breweries." (Case G).* Since they cannot join existing programs, they have to find interested receivers for their waste themselves, which turns out to be difficult in practice.

Proposition[8]: Low external interest in IS combined with a difficulty to convince companies hinders IS.

Proposition[9]: A lack of dedicated waste-valuation initiatives for breweries obstruct IS emergence.

Knowledge of external resources

Results indicate that (old) bread and damaged or leftover fruits and vegetables are the two external waste streams that are most frequently used. Only brewery C uses bread and vegetables as a standard ingredient for some of their beers. They explained it is not difficult at all to know where to find these leftovers: *"It is common knowledge and it has been in the news that lots of bakery stores have bread leftovers. We have quite some bakeries in [name city] so you just start contacting them and you eventually end up with someone. It depends on the ingredient. Besides bread, we are not actively looking for other inputs but sometimes we have a crazy idea and we contact someone to see if it works or not." (Case C).* A few other breweries use leftovers occasionally or tried it in the past. Sometimes, they are asked to use someone's leftovers, sometimes they coincidentally stumble upon leftovers within the network, and in some cases, they reach out to others. In practice, the breweries in this study do not perceive a lack of knowledge about other companies' leftovers as a barrier for IS. However, there is no platform that facilitates knowledge about leftovers, and some breweries are very willing to use alternative ingredients to prevent it from being wasted.

Proposition[10]: Facilitated information sharing about material surpluses enables IS.

Time

The emergence and implementation of IS requires several additional activities. Finding and contacting potential partners, separating and transporting waste streams, and experimenting with alternative ingredients are only a few examples. This requires time, which can also be used for other activities: *"And when you're small and dependent on your production and sales, you are simply less flexible in experimenting and making these efforts. In addition, it is very time-consuming, while you can also invest this time in your sales. This makes you earn more in the same amount of time." (Case C).* The informant in question is both able and willing to invest this time. However, three breweries (B, G, H) mentioned a lack of time as a barrier for IS activities. Another barrier is a lack of willingness to invest time in activities related to waste. Brewery E made clear every waste stream can be collected by someone for free, as long as they do not have to invest any time, effort or money to make this work. Both factors apply not only to finding a partner, but also to the additional activities necessary to organize symbiosis.

Proposition[11]: A lack of time available to setup and coordinate IS hinders the emergence.

Proposition[12]: Low willingness to invest time in waste streams hinders IS emergence.

4.3.2 Economic conditions IS

Investment possibilities and willingness

Efforts like: joining or setting up an infrastructure for bottle reuse, carbon dioxide recapturing, and water filtering systems could play a major role in closing material loops but require severe investments. Although the majority of the breweries made clear to be willing to pay a premium to close loops, five breweries mentioned they cannot afford large investments: *"It really depends on the amounts. Generally, the financial space we have apart from our core activities are quite limited." (Case D).* Besides, one brewery describes there seems to be a misconception about the expenses of closing loops: *"We try to be an example for other companies who think it [closing loops] is complicated and expensive. It is the first thing you hear: it's too expensive and time consuming, but we can show improvements can be made in a very simple way without spending a lot of time and money." (Case C).* Investments in IS are expected to be done by the party gaining the most advantage. For example, brewery A wanted to donate its spent grains to a farmer but had difficulties transporting it. Therefore, the brewery decided to pay the instalments for a trailer purchased on credit by the farmer since paying disposal costs would have been the alternative.

Proposition[13]: A lack of money and misconceptions about the true costs hinder IS emergence.

Proposition[14]: Investment willingness of the benefiting actor facilitates IS emergence.

Investment and profitability risks

It is not always easy to assess whether an investment in symbiotic practices will financially pay off: *"In case of beer, I can easily calculate how much revenue I can make, so I can run a brewery. When talking*

about waste streams however, it is complicated to figure out if and how much I will gain from it." (Case D). There degree in which breweries analyze profitability risks and calculate break-even points differs a lot. Sometimes, sustainable investments are being made based on emotional grounds: *"If it's too much, you shouldn't do it of course. But if you can handle it, you should trust it and go for it. This trust will eventually pay back in societal and economical value." (case A).* Other breweries have a more rational attitude: *"In the end, everything is being justified with data. What is the effect, how much will it save, and does it justify the investment? It can also have commercial advantages of course. I'm not saying this has to be the case, because it does not have to be a requirement." (Case F).* Although profitability is not the main goal, it does influence investment decisions.
Proposition[15]: Uncertainty about the profitability of waste valuation investments hinders IS.

<u>Waste disposal costs</u>
Grain wastes are both heavy and voluminous, resulting in significant disposal costs. To avoid these costs, seven share their spent grains with other partners. The economic motive to gain financial benefits is largely driven by high disposal costs. Consequently, this strongly enables the emergence of IS to close the loop of spent grains in the beer industry. The remaining brewery (case F) shares it with partners as well, but would have been able to dispose it for free and is not driven by financial gains. However, breweries are not solely driven by the cheapest way of getting rid of waste: *"I am willing to pay a premium. If I have pay to get rid of a waste stream, and doing this in a good way is more expensive than in a bad way, I go for the good way." (Case A).* Case G shares this opinion and pays a premium for a dedicated green waste collector with higher sustainable standards than the conventional alternative. One informant (case B) even said to be in favor of a CO2-tax to discourage unsustainable practices.
Proposition[16]: High waste disposal costs stimulate IS, but is mediated by the ecological impact of how waste is processed.

<u>Price of raw materials</u>
Malt is the only conventional ingredient that is sometimes substituted by a waste product (bread leftovers). As explained in the efforts section, half of the breweries (C, D, F, G) buy malts that are locally grown in a biological or regenerative way. These malts cost up to three times as much as alternatives and the quality is often lower but breweries are willing to pay the premium. However, the impact on the production costs is very limited: *"The costs of all the other elements, so literally the bottle, label, packaging, and production are much higher than the actual grains you use. So puzzling a lot with the grain prices barely affects the final price. I believe we calculated that a 500% inclination of our grain costs – and you would think, 500% is huge! – would result in a net increase of no more than 5 cents per bottle. 5 cents!" (Case C).* In conclusion, most cases already pay a significant premium for their ingredients. None of the informants in this study said the price of raw materials affects the malts choice, let alone substituting them by alternative waste-streams. Although the high price of grains is not the

reason to use bread leftovers as a partial substitute, it does generate an advantage: *"So if we combine an expensive grain, which has a nice story of short chains and is biologically grown, with the substitution of part of the grain bill with bread leftovers, we end up having a beer that costs the same, but is a better product. After all, you have a better story, a better ingredient and a really interesting and sustainable beer. The costs are not higher because we get the bread for free, so it reinforces each other and makes it more possible." (case C)*. However, this is only mentioned by one case.

Proposition[17]: The price of raw resources has a minor impact on the emergence of IS.

<u>Compensation for-product exchange</u>

None of the breweries demands any form of financial compensation for the by-products they exchange. The same applies to bakeries for instance, providing bread leftovers. The settlement is mostly symbolic: *"I like when it is based on trust and agreements without any financial pressure. With the bakeries, we agreed we get everything for free, but we give them a beer in return. The bakery who receives our spent grains also gets it for free, but every now and then they leave a bag of bread at our door." (Case C)*. Therefore, there is no economic incentive in this regard, while financial pressure would be a potential barrier for this brewery. One informant (case G) however, always asks growers what they consider a reasonable price for leftovers because he wants to support growers and farmers in maintaining a sustainable production.

Proposition[18]: Waste exchange is informally dealt with; no financial compensation is required.

4.3.3 Technological conditions IS

<u>Knowledge about technological potential for IS</u>

Finding symbiotic opportunities requires knowledge about the possibilities for waste-exchange as well as how to execute this. Half of the informants were either surprised by or interested in more information about examples of technological potential for waste valuation. Only the use of spent grains for (animal) consumption was widely known. Although case A, C, D, and G had significant more knowledge about the potential for (more complex) reuse compared to the rest, some potential was still unknown. Besides, many informants do not have the technological knowledge about how to incorporate waste-streams in their own production processes: *"What do we need? Several kilograms of rhubarb, and it has to be processed in a certain way. I have no idea, perhaps you can just add it but this is mostly not the case. So, we have to figure out a way to make this work." (Case A)*. This sometimes forms a barrier to the actual implementation.

Proposition[19]: A lack of knowledge about the possibilities and execution of waste to resource options hinders IS.

Technological complexity of IS

Commercial brew houses are designed for using conventional ingredients. Adding alternatives like bread can easily cause operational issues like blocked pipes and filtering problems or an overall mess. In addition, many alternative ingredients have to be added during the process, while most brew houses are closed systems to decrease contamination risks: *"We take this into account when looking for a brew house. Because we want to scale up the beer lab, we need a system including a filter which can handle things like large chunks without becoming clogged, but is also suitable to add ingredients during the process and this is not possible with every system." (Case C).* Therefore, the technologic characteristics have an influence of the possibility to use unconventional ingredients.

Proposition[20]: Many brew houses are not technically suitable for unconventional ingredient use, hindering waste-to-resource options, 'open' systems and advanced filtering systems facilitate IS.

Material quality

Wastes are often a lower quality input: *"The point is, it was just nasty beer. It was a fun experiment, but it wasn't good and it has to add some value. I don't consider it a good idea if you only do it to prevent leftovers from being wasted. We are a brewery that has to produce nice beers, we are not a brewery to use up the leftovers." (Case A).* Besides, raw materials are very consistent in product quality, while this is very questionable in case of by-products: *"It makes you dependent on the bakery for instance. If you use old bread, it always has to have the exact age, and you can only hope the bakery is as consistent as we are. That's why we don't do it." (Case E).* Although two breweries do not consider consistency of the end product an issue (C and G), the others do. However, this concern can be tackled when using it in dedicated products: *"We've considered it, but we see the quality is not consistent enough and that's the most important aspect of commercial beer. But you could use it for specialties, so seasonal products or limited editions. These only require one proper batch and then it's fine. For the core beers, the quality is too inconsistent." (Case F).* Also, the material composition of waste or leftovers is often unknown. From a technological perspective, this is problematic: *"When using conventional ingredients, you know exactly how much proteins, starch, and solid substances they contain because they are certified. So all these parameters are known, while you first have to figure these out when using alternative ingredients." (Case H).* This brewery proposes to let an external party, like a university, analyze the composition.

Proposition[21]: Lower material quality and consistency, and unknown composition of wastes hinders IS.

Proposition[22]: Facilitating waste analysis and using wastes for limited edition products enables IS.

4.3.4 Policy-related conditions IS

Limiting legislation

Two breweries (C and D) pointed out current legislations directly hinders the exchange of by-products since it is prohibited to let food leftovers flow back into the food chain without additional certifications.

However, some breweries seem unaware of these legal limitations, or try to avoid them in creative ways. A similar issue became clear after brewery C collaborated with a very small scale, local soap manufacturer to process beer leftovers in small batch soap products: everything needs to be certified. Besides certifications, administrative requirements also complicate the exchange of goods: *"So policies and legislations are limiting, and I really understand why they exist, but they make a lot of things very difficult if you exactly follow the rules. The same applies to bread leftovers. Officially, you have to register the use of others by-products in a system (…) We currently only need a certain category to pay excise duties to the customs. However, to be able to register such exchanges, we need a higher category. This makes me purchasing a rather expensive annual subscription at the government, just to be even allowed to register it." (Case C).* Furthermore, policies to stimulate sustainable practices like IS are often out of reach for small companies because they are primarily aimed at large corporates: *"From an economic perspective, there is not much stimulation. As I just said, most things are just tax deductions. (…). This means it doesn't cost the government lots of money and it stimulates large, polluting companies to change these processes. However, for young companies in their startup phase, there is nothing to gain, which is too bad." (Case D).*

Proposition[23]: Certification and administrative requirements complicate waste-valuation, hindering IS.

Proposition[24]: Policies stimulating IS are often out of reach for small companies.

<u>Difficulty obtaining permissions and certifications</u>

Informants point out obtaining waste certifications is often unfeasible for a microbrewery because the (economical) benefits do not outweigh the investments in time and money. As a result, these symbiotic exchanges do either not take place, or they take place without meeting the legal requirements. In addition, multiple breweries are involved in biological grain production. Despite their efforts – often exceeding the requirements for a biological (SKAL) certification – the breweries cannot acquire this certification when only one actor within the supply chain is not certified. This is often the case with the malthouse, since there are only a handful of Dutch malthouses that are willing to malt small batches of grains. Besides, this SKAL certificate does not come easy, nor cheap: *"Yes, fucking expensive mainly, holy shit!" (Case G).* Breweries sometimes also have too limited influence on the entire supply chain to meet the requirements. However, this is not directly related to IS.

Proposition[25]: Time and money needed to certify waste-streams outweighs the gains, hindering IS.

4.3.5 Supply chain-related conditions IS

<u>Transportation complexity</u>

The complexity of transportation does not play a major role for IS in the cases observed. Only one brewery (case A) could initially not find a receiver for the spent grains because they had difficulties transporting the large volumes of spent grains. This was solved after the purchase of the Meura Mash filter, which significantly decreases both volume and weight of the waste-stream. Although wastes are sometimes transported by the brewery, the majority of the informants either preferred or demanded the receiver to arrange the transport: *"We never canceled anyone because of logistic inconvenience. I appreciate it if a farmer picks it [spent grains] up himself. I do consider it important I don't have to do it myself."* (Case G). The exchange is hindered when the distance between the brewery and the partner are severe: *"You would look at the transportation distances again. How small can you set it up to make it economically viable? So that's the same story again: the smaller the better, because otherwise it is still crossing the entire country…" (Case D).*

Proposition[26]: Transportation arranged by the receiver enables IS emergence.

Proposition[27]: Large transportation distances between IS partners hinders waste-exchange.

Limited availability and planning of materials

Several informants (case C, F, G) consider availability and planning of by-products of great importance for (potential) IS. Two informants (case D and G) made clear that nearby bakeries rarely have bread leftovers because they do not overproduce or they donate it to charities for instance. However, brewery C points out there is quite a lot of supply in relation to the amounts needed, but still have to deal with fluctuating availability: *"But if he does not have any bread leftovers, we end up having a beer without bread which is not possible because it is supposed to contain bread. It happens that the same beer contains 20% bread on one day, and 13% on another day. This depends on his supply and we accept it as it is." (Case C).* Therefore, a certain amount of flexibility in both the recipe and the required consistency can facilitate symbiotic collaborations like these. However, not every brewery is as positive about the planning of materials: *"We've tried, but it's a lot of hassle and the bread is getting moldy very quickly. (...) You need a lot for one brew and it needs to be here at the same time, without mold. As a result, you can't ask restaurants to collect their bread for a week and we will pick it up at the end of the week. By the time we want to add it to the brew house, half of it is already moldy." (Case A).* Actors from both sides cannot always precisely predict when they have by-products available.

Proposition[28]: Limited possibility to schedule the delivery of ingredients hinders IS.

Proposition[29]: Flexibility in recipe and product consistency due to fluctuating supply enables IS.

Collection and separation

Separation of waste-streams is considered quite easy for most breweries. The storage is more challenging, some breweries have very limited space available. The perishability of spent grains is also said to be a major issue: *"Well, we have to get rid of the spent grains very fast, so we immediately leave it outside. If the container is opened, it smells a lot like silage, it's really sour. This already happens after half a day, so it is crucial to store it outside and it is being collected quickly, otherwise the authorities won't like it." (Case H).* These grains not only become moldy really fast; they are also not suitable consumption after a short period of time. Refrigerating slows down the process, but none of the breweries is willing to invest in refrigerating their waste. The Meura Mash Filter, owned by two breweries (A and D) provides the benefit of a longer storage life.

Proposition[30]: The high perishability of spent grains complicates the storage and hinders IS.

Proposition[31]: Limited space to store waste hinders IS.

<u>Low volumes of by-products</u>

Informants mentioned several opportunities for (higher order) reuse of their waste streams in collaboration with commercial parties, like using spent grains to make insulation panels, waste water to produce biofuel, or yeast to make meat-substitutes for human consumption. However, despite several meetings have taken place in the past, none of the breweries actually managed to pull of any of these collaborations because the volumes of by-products they produce: "They actually visited us, but the last thing I've heard is our scale is too small for them. *They gained so much interest from investors, they raised millions and their scale became larger than we could deliver. You know, you have to extract proteins and out of 1kg of yeast, you can extract like 50g or 100g of proteins. We produce maybe 10kg per week." (Case G).* When low volumes have to be collected at multiple locations to obtain the required amount for commercial reuse, the costs, complexity, and impact of transport increase and potential partners are less willing to collect it. As a result, water is being wasted after the brewery cannot use it anymore, spent grains end up at small local farms and yeasts are either drained or wasted together with other green waste. At least five breweries pointed out their low waste volume is an issue.

Proposition[32]: Low waste volumes hinders IS.

Barrier	Dimension	Enabler
	Social	
	Willingness to collaborate	**P[1]:** High willingness of microbreweries to cooperate
P[2]: Conflicting goals and visions between actors	**Mental distance**	**P[3]:** Richness of collaborations
P[5]: A lack of trust in the receivers' intentional use of resources	**Trust**	**P[4]:** Informal, trust-based agreements rather than contracts
P[6]: A lack of network diversity	**Network diversity**	**P[7]:** Entering existing local communities
P[8]: Low external interest in IS combined with a difficulty to convince companies **P[9]:** A lack of dedicated waste-valuation initiatives for breweries	**External interest in IS**	
	Knowledge about others resources	**P[10]:** Facilitated information sharing about material surpluses
P[11]: A lack of time available to setup and coordinate IS **P[12]:** Low willingness to invest time in waste streams	**Time**	
	Economic	
P[13]: A lack of money and misconceptions about the true costs about closing loops	**Investment possibilities and willingness**	**P[14]:** Investment willingness of the benefiting actor
P[15]: Uncertainty about the profitability of waste valuation investments	**Profitability risks**	
	Waste disposal costs	**P[16]:** High waste disposal costs stimulate IS, but is mediated by the ecological impact of the processing
	Price of raw materials	**P[17]:** The price of raw resources has a minor impact on the emergence of IS
	Revenues of by-product exchange	**P[18]:** Waste exchange is informally dealt with; no financial compensation is required
	Technological	
P[19]: A lack of knowledge about the possibilities & execution of waste-to-resource options	**Tech. knowledge about IS potential**	
P[20]: Many brew houses are not technically suitable for unconventional ingredients.	**Technological complexity**	**P[20]:** "Open" production systems and advanced filtering systems
P[21]: Lower material quality and consistency, and unknown composition of wastes	**Material quality**	**P[22]:** Facilitating waste analysis and using wastes for limited edition products
	Policy-related	
P[23]: Certification and administrative requirements complicate waste-valuation **P[24]:** Policies stimulating IS are often out of reach for small companies	**Limiting legislation**	
P[25]: Time and money needed to certify waste-streams outweighs the gains	**Difficulty of obtaining certifications**	
	Supply Chain	
P[27]: Large transportation distances between IS partners	**Transport**	**P[26]:** Transportation arranged by the receiver
P[28]: Limited possibility to schedule the delivery of ingredients	**Planning & availability received materials**	**P[29]:** Flexibility in recipe and product consistency due to fluctuating supply
P[30]: The high perishability of spent grains complicates the storage **P[31]:** Limited space to store waste	**Collection and separation**	
P[32]: Low waste volumes hinders IS	**Low volumes**	

Table 4: Overview of all IS condition-related propositions

4.4 IS conditions in relation to the emergence process

The conditions mentioned in the previous paragraph do not play an equally important role in the emergence of IS, and also affect different core activities of the IS emergence process as described by Mortensen and Kørnøv (2019). In this paragraph, the relations between the conditions and emergence activities will be explained, based on the propositions formulated. This answers the last sub-question. All figures, including an overview of the full process can be found in high resolution in appendix 4.

4.4.1 Creating awareness and interest in IS

Organizations need to be aware of the potential and benefits of IS, and need a certain stimulation to engage in these collaborations. This activity takes place within the organizational borders. It is striking that the interest in IS and the focus on circularity is strongly based on intrinsic motivations and the ecological motives are deeply rooted in the identity of seven breweries within this study: *"It's just, we have kind of protocol we use to make all decisions and… This is simply who we are. Circularity and treating the planet in a right way and leave a small footprint is part of it, we just do this." (Case A).* Social, but primarily the ecological motives foster this internal interest, resulting in practices that are consequently measured in terms of the organizations ecological ideals. High costs of waste disposal (P^{16}) drive the economic motive to save money, generating interest in IS. One informant (case C) made clear using wastes they receive for free helps them to compensate higher prices of more sustainable raw resources they also use (P^{17}); however, this enabling factor was only mentioned once, making it less dominant. The possibility to create new market opportunities by collaborative waste-valuation also stimulates the internal interest among the cases, but in much less extent than ecological motives. None of the informants experience legal requirements as a driving force towards interest in IS. Instead, policies are often not aimed at small companies (P^{24}), hindering incentives to engage in IS. Breweries tend to have a very high willingness to collaborate in general (P^{1}), facilitating awareness and interest in IS to close loops as well. When discussing examples of potential waste-to-resource possibilities with brewing waste, it became apparent about half of the cases had only limited knowledge about the potential of their wastes, but were interested in receiving more information. This shows a lack of technological knowhow about potential opportunities for IS, and how they could be realized in practice (P^{19}) forms a severe barrier towards internal interest and awareness in IS. Waste costs are the only important economic enabler, and further IS emergence is limited by a lack of knowledge about technological possibilities. An overview of how the *creating awareness and interest* activity relates to the conditions and propositions can be found in figure 7.

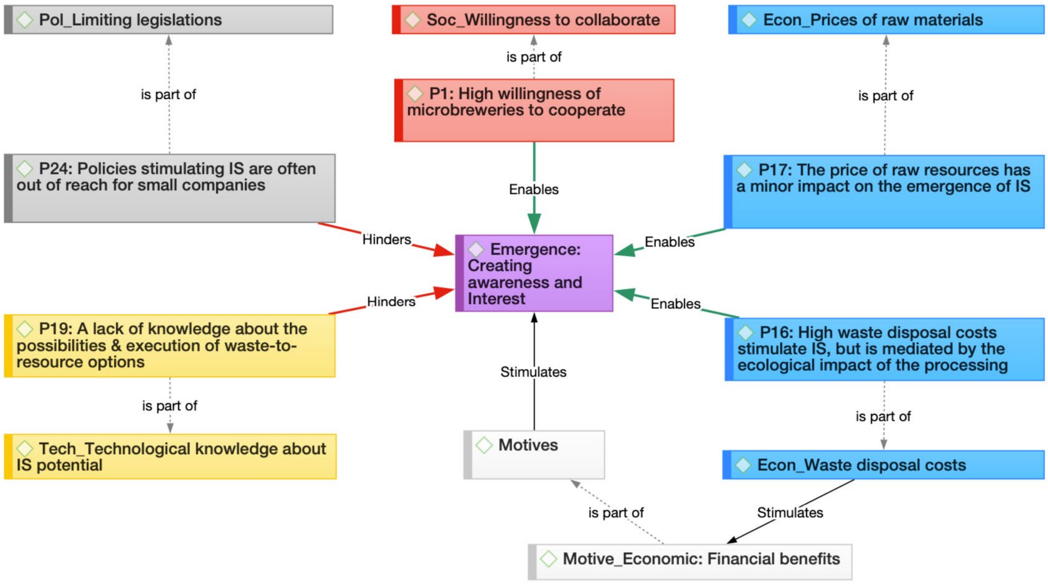


Figure 7: Conditions in relation to the Awareness & Interest activities

4.4.2 Reaching out and exploration of connections between actors

This emergence step entails finding potential partners to collaborate with, as well as assessing the fit between the different actors. The interviews made clear that breweries are rarely contact by external parties to talk about symbiotic opportunities. A lack of own network diversity (P^6) is frequently mentioned as a severe barrier towards IS, requiring companies to actively search for partners to exchange leftovers and wastes with: *"Both searching on Google, and using your network. I have been googling and calling people a lot of people, especially in the beginning. Currently, I have a pretty good network so I can also just ask people." (Case G).* Although these efforts help expanding the network, making it easier to find the right people, informants propose facilitation of information sharing about leftovers and waste streams (P^{10}). This enables finding an IS partner to avoid unnecessary waste. Besides, active efforts to find surpluses and the right partners are very time consuming and informants do not always have this time (P^{11}). Besides, the informants are often not willing to invest much time in their waste (P^{12}), especially when they already have a practical solution to get rid of it. Although joining local networks of entrepreneurs is said to be helpful to expand the network and find similar-minded local actors (P^7), there are barely any existing initiatives aimed at brewing wastes, so there is also no easy way to get in touch with the right people (P^9). When brewers are in touch with a potential partner, they are often turned off due to conflicting motivations and values (P^2). A collaboration which goes beyond the waste exchange is preferred (P^3). Furthermore, external parties are often not (yet) interested in IS, and convincing them is perceived as difficult (P^8). Finally, although the cases in this study do not experience trust issues from their sides, some potential partners are hesitant to share free leftovers out of fear they will be used for other purposes than proposed (P^5). The results in figure 8 show this activity of the emergence process is strongly impacted by social conditions.

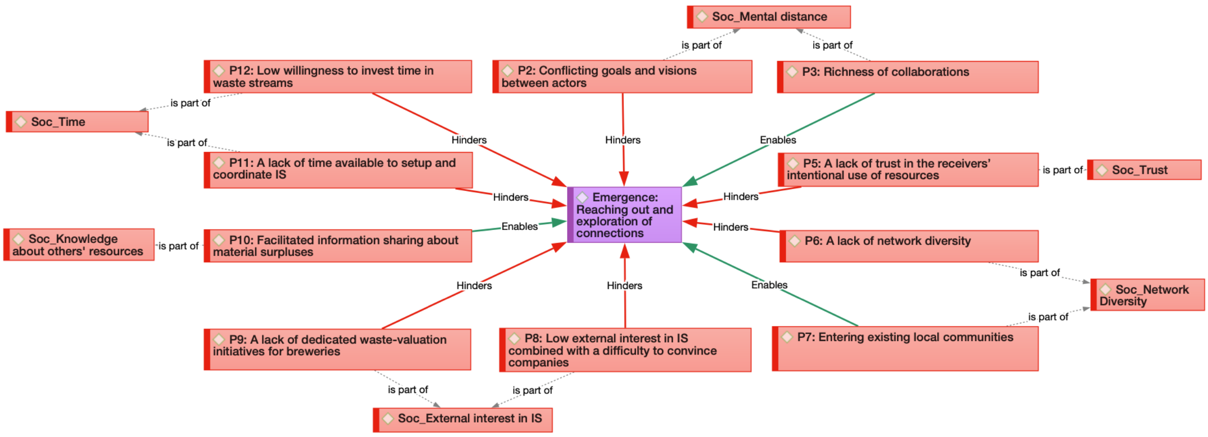


Figure 8: Conditions in relation to the Reaching Out and Exploration of Connections activities

4.4.3 Organizing IS

This activity consists of the early development of symbiotic practices, and their feasibility assessment. Implementing material exchanges in the processes requires several additional efforts. Similar to the *reaching out*-activities, time is an important limiting factor (P[11]) when organizing or trying out IS. Arrangements with partners are preferably based on trust (P[4]), and compensations for waste exchanges are favored in a symbolic way (P[18]). Informants made clear it is often assumed closing loops requires large investments, and most breweries do not have much budget, hindering IS (P[13]). This can be solved if the beneficial partner is willing to invest (P[14]). Besides, four technological factors play a role. Efforts are sometimes not being made, or end up unsuccessful due to a lack of technological knowledge, which also hinders the internal awareness (P[19]). Furthermore, existing machinery and infrastructure is not always suitable for the use of unconventional ingredients (P[20]), and these ingredients have lower quality standards (P[21]) which negatively impacts the final product. This is an important reason for breweries not to incorporate waste streams in their production. The quality issue is decreased when waste-streams are analyzed before the exchange, and inconsistencies are easier to accept with single batch products (P[22]). Informants described multiple situations in which conversations with potential commercials partners did not lead to IS because of supply chain issues. The volumes of the breweries' by-products were sometimes way too low, making it economically unfeasible for the partner (P[32]). This often goes hand in hand with transportation issues, particularly too long distances between partners (P[27]). A receiver arranging waste transportation facilitates IS (P[26]). Also, the challenge and associated risks of being able to obtain sufficient volume of alternative inputs at the desired moment strongly impacts the feasibility of a symbiotic collaboration (P[28]). Cases accepting more inconsistency in recipes and the final product are less prone to supply and delivery limitations (P[29]). Separating and storing waste complicate the emergence of IS, because some ingredients rapidly become moldy (P[30]), and multiple informants pointed out to have very limited space available (P[31]). Finally, both policy-related conditions negatively impact the feasibility of waste-to-resource options due to limiting legislations (P[23]) and bureaucratic and expensive procedures to get certifications (P[25]).

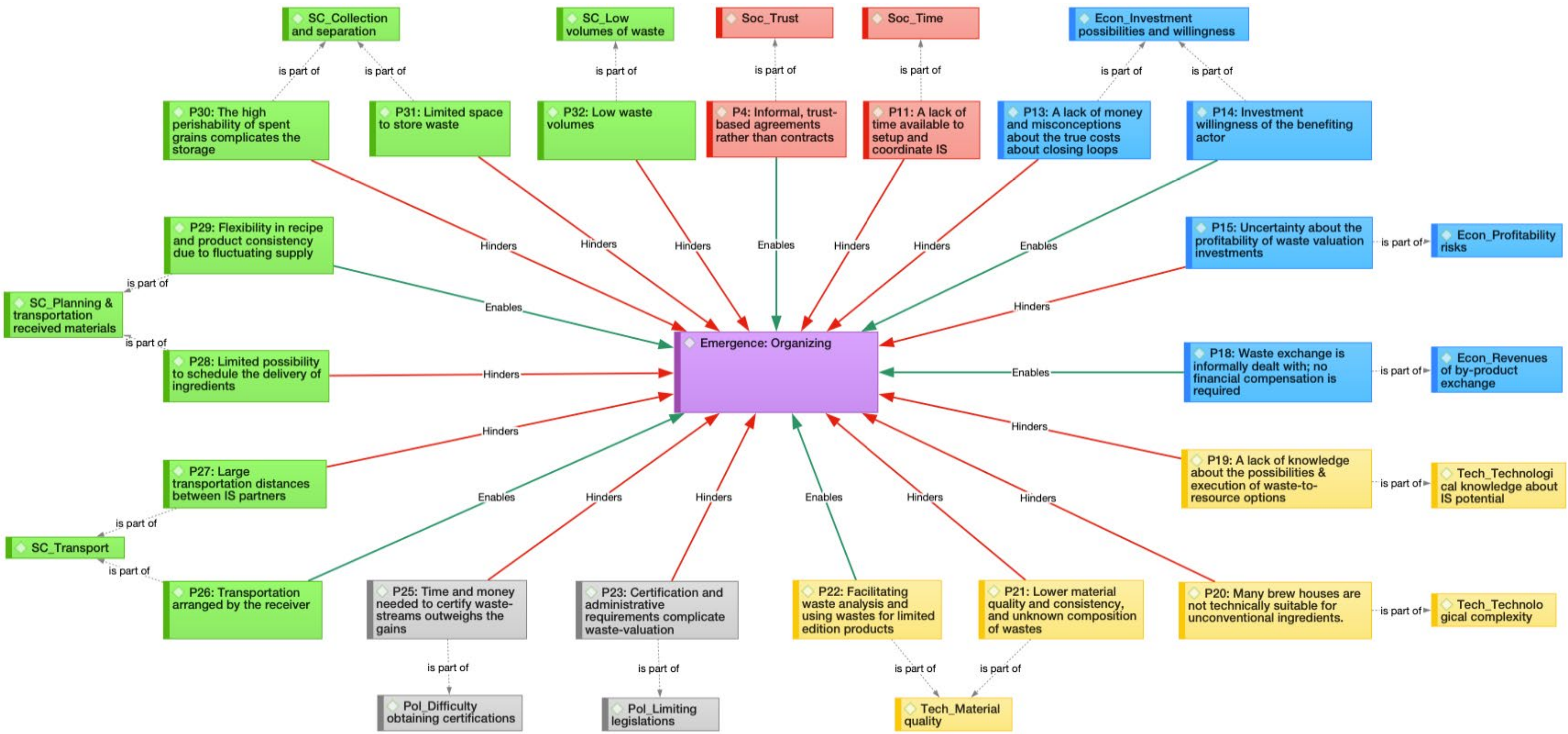


Figure 9: Conditions in relation to the Organizing activities

Chapter 5. Conclusion & discussion

In the previous chapter, the results of the empirical part of this study are described. In this chapter, the research question will be answered, followed by a discussion explaining the theoretical and practical implications of the outcomes. Finally, the limitations of this study will be discussed and suggestions for further research will be given.

5.1 Conclusion

The aim of this research was to explore how Dutch microbreweries can convert their wastes into resources through IS in a CE. In order to answer the research question: "*how can Dutch microbreweries successfully contribute to a circular economy by closing material loops through Industrial Symbiosis?"*, this study focused on which circular efforts the cases have already made, as well as their motives to do so. Furthermore, an in-depth description of which conditions influence the breweries' engagement in IS, and how these conditions impact the different core activities of the IS emergence process has been given. This resulted in a list of 32 propositions, divided over the three aspects of the emergence process, providing an overview of all proposed relations.

The results show there is a large variety of IS opportunities in the Dutch microbrewery industry. Although some are already common practice in all cases (f.i. spent grains exchange with farms), most are still underexploited. This indicates there is still much potential for collaborative waste-to-resource options in the industry. The vast majority of the breweries in this study have strong intrinsic motives to engages in circular and IS practices, reflecting personal values of the owners or managers. Ecologic aspects appear most dominant, but social aspects like the supporting regional companies also play a role. From an economic perspective, the extrinsic motivation of reducing resource and waste disposal costs also raises interest in IS, but financial gains were not the primary aim for most cases. However, IS often generates new market opportunities, providing new commercial benefits as well. Overall, the conclusion can be drawn that breweries already have clear motivations to engage in IS, and ecologic motives to seems to be more important than economic ones. The motivations are primarily intrinsic, and firms are not forced or externally stimulated.

Linking the conditions affecting the emergence of IS with the three core activities of the process makes clear enabling factors are largely overshadowed by barriers, hindering companies to close loops. In terms of creating interests and awareness of the possibilities of IS within the firms, insufficient knowledge about the technological opportunities, as well as lacking stimulating policies which are applicable to SMEs hinder the emergence. Besides, finding the right partners for a collaboration often turns out difficult due to multiple social factors. These are often related to the absence of existing IS initiatives and platforms which facilitates companies to get in touch with similar-minded actors from relevant industries, or convinces them of the mutual benefits. As a result, IS does often not take place because it requires too much time and active efforts to find the right connections, and external actors are often not interested in waste exchange. This emphasizes the importance of networking and mediating activities to find the right company fit in terms of both resource needs and surpluses, as well as similar mindsets.

When trying to organize potential IS activities, logistical, financial, and technological challenges complicate the process, making actual implementation less feasible for microbreweries. Waste volumes are often too low and difficult to schedule in advance, the quality is lower than conventional ingredients, and breweries do not always possess sufficient knowledge and machinery to integrate it in the production process. An important problem is that best practices for breweries are unavailable, so they have to figure out ways to make waste valuation work themselves, creating an additional workload next to the core activities. Besides, firms are often not willing to invest in their wastes, and waste valuation is often considered too expensive. However, this study also shows examples of affordable practices, proving the opposite in terms of costs. Finally, existing policies and certification requirements of waste-valuation are not suitable for practices on a small scale, making it difficult for small companies to comply with the regulations. This indicates (local) governments also play an important role in the transition towards closed loop production, and may need to revisit its policies to facilitate IS. Overall, this study shows Dutch microbreweries are mostly willing and motivated to engage in IS, but are not externally stimulated to do so. Besides, intervening conditions are often unfavorable for IS to happen on a small scale. Multiple enabling factors are identified as well, but results show they do not outweigh the limitations of the barriers experienced by the cases. Therefore, more support and facilitation are needed to make collaborative waste-valuation work for Dutch microbreweries. A shift from the current self-organized model to a facilitated model is favorable for further IS emergence.

5.2 Theoretical implications

Chertow (2007) stretches out the importance of being aware of becoming part of a symbiotic network in order to develop effective IS and argues economic factors drive companies to collaborate to obtain competitive advantage. However, the results of this study do not support this statement. Economic factors like waste disposal costs do stimulate firms to seek for IS, but the willingness of several cases to pay a premium for more sustainable disposal methods shows gaining competitive advantage is not the primary driver in the context of closing material loops. This implies firms have different motives when seeking for ways to close loops than when looking for generic symbiotic possibilities. In addition, Costa and Ferrão (2010) mention ecological motives are generally the result of forcing or stimulating legislations. This study shows the opposite: seven out of eight breweries have very strong ecological motives, despite none of the informants experienced any applicable policies stimulating IS. In fact, policy is mentioned as one of the factors hindering symbiotic waste-exchange on a small scale. Overall, the results of this study imply ecological motives are more intrinsic and seem to play a more important role in the emergence of IS with the aim to close material loops than described by scholars in a general IS context. In addition, social motives for IS are not frequently mentioned in literature, while they did appear to play a role as well. Most research in the field of IS focused on large companies, the results of this study make clear SMEs have different, less economic motives which enriches the existing literature.

When looking at the organization of IS, all examples in this research are based on self-organized models, which are said to be driven by self-interests of the actors involved (Chertow, 2007). Although mutual benefits are expected by the cases observed, several breweries expect similar mindsets and responsible use of the resources as a requirement for IS, which shows the reaching out process is not solely based on rational economic arguments.

In terms of conditions affecting waste-to-resource implementation, most of the conditions identified in the literature study appeared relevant to the cases within this study, but the way they impact IS sometimes differs. This supports the importance of taking into account local contexts when setting up IS (Henriques et al., 2021). For instance, a lack of trust between actors to share internal information is said to hinder the emergence of IS (Neves et al., 2019). However, multiple informants made clear they have no reason not to trust a potential partner if there is no clear reason to and made clear to be very willing to share knowledge with competitors to make the industry more sustainable as a whole. At the same time, informal, trust-based agreements appeared to be a preferred way to make arrangements. Therefore, trust can also be an enabling factor in terms of organizing IS in the perspective of closing loops. Overall, the conditions affecting IS emergence turn out to be highly complex, and require in-depth exploration in the natural context of the phenonium, making it very difficult to setup general guidelines for firms.

5.3 Practical implications and recommendations

This study provides more in-depth knowledge about which conditions, and how these conditions impact the IS emergence when the primary aim is to close material loops by creating waste-to-resource options. From a practical point of view, information about enabling factors can be helpful when trying to setup IS collaborations. For instance, joining existing local communities can facilitate network extension on a local level. However, there are several barriers that needs to be taken away in order to accelerate a circular transition. One barrier that can be partially taken away based on this study is the misconception about the true costs of waste valuation. Knowing there are several ways to close loops through IS without the need for large investments may already motivate microbreweries to try it. More important, cross-industrial knowledge platforms and exchange facilitators can play an important role in taking away barriers by sharing best practices and arrange partner matching. This reduces the need for individual firms to invest time to find and convince potential partners, seek for resource surpluses, and experiment with the integration of waste-streams in the production processes. An example of an organization which could be suitable to coordinate this is CRAFT, a Dutch association representing 160 independent breweries. Some supply chain related issues can also be solved by coordinating intermediaries. For instance, multiple breweries in the same region could join forces and collaboratively try to setup symbiotic practices, generating larger volumes of waste, and making logistics more efficient so IS becomes more viable on a larger commercial scale. Besides, larger volumes are also more feasible to certify. Collaborations between breweries can also enable them to offer a more constant supply of materials, since multiple companies can make up for each other when a waste stream is not available at the desired moment. Individual breweries could also make efforts to facilitate IS emergence. For instance, by including material flow and waste management as a core activity in daily operations. This does not require additional staff, but can already be effectuated by relatively small tasks like joining local network events and circular platforms, and frequently discussing practices with other breweries. The latter does not only stimulate knowledge sharing, but also raises more awareness within the sector.

From a governmental point of view, the outcomes of this study make clear (local) governments and policy-makers play an important role in a transition towards circularity. Policies to stimulate or facilitate IS do already exist in the form of tax-benefits or subsidies, but they do not apply to small companies or startups. Subsidies are often out of reach due to a lack of employees, and tax benefits are not stimulating when revenues are still low. This is problematic, since the European Union already acknowledged the importance of the circular transition by introducing the Circular Economy Action plan. It is important for policy-makers to critically revisit existing legislations in order to facilitate a circular transition among small companies as well. Besides, certification requirements for reuse seem to be established with large commercial processes in mind. This may work fine for corporates, but it makes waste-valuation very difficult on a small, local scale. Furthermore, governments could boost a transition by setting up or promoting existing circularity communities. Although some initiatives already exist, breweries in this study turned out not aware of the possibility to receive advice and assistance.

5.4 Limitations & suggestions for further research

This research also has some limitations. In order to gain in-depth knowledge about how IS could contribute to closing material loops in a circular perspective, the cases are selected based on a sustainable orientation. However, this affects the degree in which the cases are representative for the entire craft beer industry. Consequentially, more research is necessary to compare the motives and willingness to engage in IS with breweries with lower sustainability focus. In addition, the fact some breweries set up waste exchanges without economic benefits show the ecological motive is important. It is still unclear whether this is only caused by personal interests of the managers or owners, or if it also has to do with (a lack of) economies of scale, reducing the economic gains. One of the reasons to select microbreweries for this study is the statement they are running behind on their larger counterparts in terms of ecological sustainability (Jones, 2018). The outcomes of this study indicate a very strong ecological motive, and show multiple breweries meet all requirements for sustainable certifications, but decided not to go through the expensive and bureaucratic process to become actually certified. This raises the question whether smaller breweries are actually less sustainable, or if the (often quantitative) measures used to assess this are less suitable for smaller companies. The study has exclusively focused on breweries, and did not take other actors in existing symbiotic networks into account. Since IS requires multiple actors from different industries, a better understanding of the influencing factors can be provided by taking into account the full network. This is particularly important because breweries experienced external parties are often less interested in IS. More knowledge about how they could effectively be stimulated to implement waste-valuation can contribute to a transition on a larger scale. Finally, this research has explored the intervening factors like motivations, enablers and barriers for IS in the microbrewing industry. A next step towards mapping best practices would be to conduct a follow-up study focused on the following phase of the implementation tool of Azevedo et al. (2021), which is developing the implementation strategy for IS since there is a large need for best practices.

References

Azevedo, J., Henriques, J., Estrela, M., Dias, R., Vladimirova, D., Miller, K., & Iten, M. (2021). Guidelines for Industrial Symbiosis—a Systematic Approach for Content Definition and Practical Recommendations for Implementation. *Circular Economy and Sustainability*. doi:10.1007/s43615-021-00006-3

Baas, L. W., & Boons, F. A. (2004). An industrial ecology project in practice: exploring the boundaries of decision-making levels in regional industrial systems. *Journal of cleaner production, 12*(8-10), 1073-1085.

Bleijenbergh, I. (2015). *Kwalitatief onderzoek in organisaties* (Tweede druk. ed.). Den Haag: Boom Lemma uitgevers.

Bocken, N. M. P., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33*(5), 308-320. doi:10.1080/21681015.2016.1172124

Boons, F., Chertow, M., Park, J., Spekkink, W., & Shi, H. (2017). Industrial symbiosis dynamics and the problem of equivalence: Proposal for a comparative framework. *Journal of Industrial Ecology, 21*(4), 938-952.

Boons, F., Spekkink, W., & Mouzakitis, Y. (2011). The dynamics of industrial symbiosis: a proposal for a conceptual framework based upon a comprehensive literature review. *Journal of cleaner production, 19*(9-10), 905-911. doi:10.1016/j.jclepro.2011.01.003

Brennan, G., Tennant, M., & Blomsma, F. (2015). Business and production solutions: closing loops and the circular economy. Retrieved from https://eprints.mdx.ac.uk/21177/1/Brennan

CBS. (2017, June 13). Aantal bierbrouwers meer dan verviervoudigd sinds 2007. Retrieved from https://www.cbs.nl/nl-nl/nieuws/2017/24/aantal-bierbrouwers-meer-dan-verviervoudigd-sinds-2007

Chertow, M. R. (2000). INDUSTRIALSYMBIOSIS: Literature and Taxonomy. *Annual Review of Energy and the Environment, 25*(1), 313-337. doi:10.1146/annurev.energy.25.1.313

Chertow, M. R. (2007). "Uncovering" Industrial Symbiosis. *Journal of Industrial Ecology, 11*(1), 11-30. doi:10.1162/jiec.2007.1110

Chertow, M. R., Ashton, W. S., & Espinosa, J. C. (2008). Industrial Symbiosis in Puerto Rico: Environmentally Related Agglomeration Economies. *Regional Studies, 42*(10), 1299-1312. doi:10.1080/00343400701874123

Costa, I., & Ferrão, P. (2010). A case study of industrial symbiosis development using a middle-out approach. *Journal of cleaner production, 18*(10-11), 984-992.

Davis, S. C., Kauneckis, D., Kruse, N. A., Miller, K. E., Zimmer, M., & Dabelko, G. D. (2016). Closing the loop: integrative systems management of waste in food, energy, and water systems. *Journal of Environmental Studies and Sciences, 6*(1), 11-24.

De Jesus, A., & Mendonça, S. (2018). Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. *Ecological economics, 145*, 75-89.

Diener, E., & Crandall, R. (1978). *Ethics in social and behavioral research*: U Chicago Press.

Domenech Aparisi, T. (2010). *Social aspects of industrial symbiosis networks.* UCL (University College London),

Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., & Roman, L. (2019). Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. *Resources, Conservation and Recycling, 141*, 76-98.

Doménech, T., & Davies, M. (2011). The role of embeddedness in industrial symbiosis networks: Phases in the evolution of industrial symbiosis networks. *Business Strategy and the Environment, 20*(5), 281-296.

Dora, M. (2019). Collaboration in a circular economy. *Journal of Enterprise Information Management, 33*(4), 769-789. doi:10.1108/jeim-02-2019-0062

Ellen MacArthur Foundation. (2013). Towards the circular economy. *Journal of Industrial Ecology, 2*, 23-44. Retrieved from https://www.werktrends.nl/app/uploads/2015/06/Rapport_McKinsey-Towards_A_Circular_Economy.pdf

Ellen MacArthur Foundation. (2015). Towards a circular economy: Business rationale for an accelerated transition. Retrieved from https://www.ellenmacarthurfoundation.org/publications

Ellen MacArthur Foundation. (2019). Completing the Picture: How the Circular Economy Tackles Climate Change. Retrieved from www.ellenmacarthurfoundation.org/publications

European Commission. (2020). *A new Circular Economy Action Plan For a cleaner and more competitive Europe*. Brussels Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

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

Hazen, B. T., Russo, I., Confente, I., & Pellathy, D. (2021). Supply chain management for circular economy: conceptual framework and research agenda. *The International Journal of Logistics Management, 32*(2), 510-537. doi:10.1108/ijlm-12-2019-0332

Henriques, J., Ferrão, P., Castro, R., & Azevedo, J. (2021). Industrial Symbiosis: A Sectoral Analysis on Enablers and Barriers. *Sustainability, 13*(4), 1723. doi:10.3390/su13041723

Jones, E. (2018). Brewing Green: Sustainability in the Craft Beer Movement. *Craft Beverages and Tourism, Volume 2*, 9. Retrieved from http://ndl.ethernet.edu.et/bitstream/123456789/69400/1/204%202018.pdf#page=23

Kalmykova, Y., Sadagopan, M., & Rosado, L. (2018). Circular economy–From review of theories and practices to development of implementation tools. *Resources, Conservation and Recycling, 135*, 190-201.

Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: a global snapshot of solid waste management to 2050*: World Bank Publications.

Kazancoglu, I., Kazancoglu, Y., Yarimoglu, E., & Kahraman, A. (2020). A conceptual framework for barriers of circular supply chains for sustainability in the textile industry. *Sustainable development, 28*(5), 1477-1492. doi:10.1002/sd.2100

King, A. M., Burgess, S. C., Ijomah, W., & McMahon, C. A. (2006). Reducing waste: repair, recondition, remanufacture or recycle? *Sustainable development, 14*(4), 257-267.

King, N., Brooks, J., & Tabari, S. (2018). Template analysis in business and management research. In *Qualitative methodologies in organization studies* (pp. 179-206): Springer.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: evidence from the European Union (EU). *Ecological economics, 150*, 264-272.

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

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: the concept and its limitations. *Ecological economics, 143*, 37-46. Retrieved from https://doi.org/10.1016/j.ecolecon.2017.06.041

Leach, M., Raworth, K., & Rockström, J. (2013). Between social and planetary boundaries: Navigating pathways in the safe and just space for humanity. Retrieved from http://www.worldsocialscience.org/documents/wss-report-2013-part-1.pdf#page=21

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

Madsen, J. K., Boisen, N., Nielsen, L. U., & Tackmann, L. H. (2015). Industrial symbiosis exchanges: Developing a guideline to companies. *Waste and biomass valorization, 6*(5), 855-864.

Merli, R., Preziosi, M., & Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. *Journal of cleaner production, 178*, 703-722.

Mirata, M., & Emtairah, T. (2005). Industrial symbiosis networks and the contribution to environmental innovation: The case of the Landskrona industrial symbiosis programme. *Journal of cleaner production, 13*(10-11), 993-1002.

Mishra, J. L., Hopkinson, P. G., & Tidridge, G. (2018). Value creation from circular economy-led closed loop supply chains: a case study of fast-moving consumer goods. *Production Planning & Control, 29*(6), 509-521. doi:10.1080/09537287.2018.1449245

Mortensen, L., & Kørnøv, L. (2019). Critical factors for industrial symbiosis emergence process. *Journal of cleaner production, 212*, 56-69. doi:10.1016/j.jclepro.2018.11.222

Nederlandse Brouwers. (n.d.). Bier & Economie. Retrieved from https://www.nederlandsebrouwers.nl/biersector/bier-en-economie/

Neves, A., Godina, R., G. Azevedo, S., Pimentel, C., & C.O. Matias, J. (2019). The Potential of Industrial Symbiosis: Case Analysis and Main Drivers and Barriers to Its Implementation. *Sustainability, 11*(24), 7095. doi:10.3390/su11247095

Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H., Clement, J., . . . Droz-Georget, H. (2019). Global resources outlook 2019: Natural resources for the future we want. Retrieved from http://pure.iiasa.ac.at/id/eprint/15879/1/unep_252_global_resource_outlook_2019_web.pdf

Olajire, A. A. (2020). The brewing industry and environmental challenges. *Journal of cleaner production, 256*, 102817. Retrieved from https://doi.org/10.1016/j.jclepro.2012.03.003

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and policy in mental health and mental health services research, 42*(5), 533-544.

Patala, S., Salmi, A., & Bocken, N. (2020). Intermediation dilemmas in facilitated industrial symbiosis. *Journal of cleaner production, 261*, 121093.

Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of cleaner production, 179*, 605-615. Retrieved from https://doi.org/10.1016/j.jclepro.2017.12.224

Reike, D., Vermeulen, W. J., & Witjes, S. (2018). The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling, 135*, 246-264. Retrieved from https://doi.org/10.1016/j.resconrec.2017.08.027

Ritzén, S., & Sandström, G. Ö. (2017). Barriers to the Circular Economy–integration of perspectives and domains. *Procedia Cirp, 64*, 7-12.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., . . . Schellnhuber, H. J. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and society, 14*(2).

Schut, E., Crielaard, M., & Mesman, M. (2016). Circular economy in the Dutch construction sector: A perspective for the market and government.

Staples, A. J., Reeling, C. J., Widmar, N. J. O., & Lusk, J. L. (2020). Consumer willingness to pay for sustainability attributes in beer: A choice experiment using eco-labels. *Agribusiness, 36*(4), 591-612.

Strähle, J., & Philipsen, F. (2017). Closed-Loop Production: A Literature Review. In (pp. 27-47): Springer Singapore.

United Nations. (n.d.). Goal 12: Ensure sustainable consumption and production patterns. Retrieved from https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

United Nations Department of Economic & Social Affairs. (2019). 2019 Revision of World Population Prospects. Retrieved from https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

Vennix, J. A. M. (2019). *Research methodology: An introduction to scientific thinking and practice*: Pearson [Benelux BV].

Winans, K., Kendall, A., & Deng, H. (2017). The history and current applications of the circular economy concept. *Renewable and Sustainable Energy Reviews, 68*, 825-833. Retrieved from https://doi.org/10.1016/j.rser.2016.09.123

Winkler, H. (2011). Closed-loop production systems—A sustainable supply chain approach. *CIRP Journal of Manufacturing Science and Technology, 4*(3), 243-246. doi:10.1016/j.cirpj.2011.05.001

Yin, R. K. (1994). Case study research: Design and methods, applied social research. *Methods series, 5*.

Yu, Y. F., Yazan, D. M., Bhochhibhoya, S., & Volker, L. (2021). Towards Circular Economy through Industrial Symbiosis in the Dutch construction industry: A case of recycled concrete aggregates. *Journal of cleaner production, 293*, 15. doi:10.1016/j.jclepro.2021.126083

Zhijun, F., & Nailing, Y. (2007). Putting a circular economy into practice in China. *Sustainability Science, 2*(1), 95-101.

Appendix 1: Interview protocol

Dit onderzoek gaat over hoe Nederlandse microbrouwerijen kunnen bijdragen aan een circulaire economie. Meer specifiek, hoe zij materiaal- en afvalstromen kunnen sluiten middels samenwerkingen met andere organisaties. Het sluiten van materiaal- en afvalstromen houdt in dat bedrijven in verschillende branches restproducten met elkaar uitwisselen zodat deze kunnen worden hergebruikt in plaats van dat deze worden weggegooid. Hierdoor worden materialen efficiënter benut en wordt onnodig afval voorkomen. Dit houdt ook in dat benodigdheden voor het productieproces indien mogelijk zoveel mogelijk worden vervangen door alternatieven voor ruwe grondstoffen.

De data uit dit interview wordt strikt geanonimiseerd verwerkt om ervoor te zorgen dat de data niet herleidbaar is. Dit houdt in dat zowel uw naam als die van uw brouwerij niet worden opgenomen in de transcripten en in het uiteindelijke onderzoek. Het transcript van het interview stuur ik u uiterlijk een week na het interview toe zodat u deze kunt controleren en indien gewenst kunt aanpassen. U kunt tot het moment van goedkeuring van het transcript besluiten om u volledig terug te trekken uit het onderzoek.

Wel zou ik het gesprek graag opnemen om het uitwerken van de transcripten mogelijk te maken. Gaat u hiermee akkoord?

Introductie:
- Wanneer is uw brouwerij opgericht?
- Wat is de specialiteit van de brouwerij? Wat is uw functie?
- Kunt u een korte omschrijving geven van uw organisatie?
- Kunt u uw bedrijfsmodel kort toelichten? (Omzet, jaarlijkse productie in HL, werkgebied)
- Maakt uw brouwerij deel uit van een ander concern dat zich bezighoudt met bierproductie?

Bent u bekend met het begrip circulariteit, en zo ja: wat verstaat u hieronder?

"An economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."

1. Awareness & interest (internal)

Bent u binnen de brouwerij bezig met circulariteit?

Zo ja: Wat is uw motief om dit te doen (economisch, ecologisch, wetgeving)?
Welke activiteiten heeft u ondernomen?
Hoe wordt circulariteit binnen de brouwerij gestimuleerd?
Wat is hierin uw ambitie en waar staat u nu?

Zo nee: Waarom niet?
Wat zou er nodig zijn om circulariteit prioriteit te geven binnen uw organisatie?

2. Reaching out & exploration of connections (external)

Dit onderzoek is specifiek gericht op Industrial Symbiosis, dit is een samenwerkingsconcept waarin verschillende industrieën die normaal gesproken zelfstandig opereren juist gaan samenwerken om competitief voordeel op te doen. Dit kan worden bereikt door het uitwisselen van materialen, energie, water en/of restproducten. De focus in dit onderzoek ligt vooral op het uitwisselen van materiaal en afvalstromen.

Werkt u samen met andere partners om uw materiaal- en afvalstromen te sluiten?

zo ja: Kunt u een aantal voorbeelden noemen?
Waarom bent u deze samenwerking(en) gestart?
Hoe belangrijk is samenwerken voor u?
Hoe heeft u deze partners gevonden?
Aan welke eisen moeten deze voldoen en hoe selecteert u die?
Tegen welke uitdagingen bent u aangelopen en hoe heeft u deze opgelost?

Zo nee: Waarom niet?
Wat zou er nodig zijn om deze samenwerkingen wel aan te gaan?

Hoe versterkt de samenwerking de mate waarin u circulair werkt?
Hoe verbetert de samenwerking uw eigen organisatie? (Of het technologisch proces)
Wat is het belang voor de andere partij?
Kan dit op een andere manier worden gerealiseerd?

3. Organizing (concepts + feasibility)

Input

Welke grondstoffen/materialen en producten gebruikt u voor uw productie?

Hoe komt u hieraan?

Bent u bekend met duurzamere alternatieven ter vervanging hiervan?

Zo ja: welke? Op welke manier?

Maakt u hier gebruik van? Waarom (niet)?

Zo ja: wat maakte dit hergebruik mogelijk? Welke **barrières** bent u tegengekomen en hoe heeft u deze overwonnen? Op basis waarvan beslist u of een optie haalbaar voor u is?

Wat heeft u nodig om dit hergebruik nog verder te stimuleren?

Zo nee: waarom gebruikt u deze niet?

Wat is er nodig om u van gedachten te laten veranderen? Wat kunnen anderen doen om voor u mogelijk te maken?

Zo nee: (benoemen enkele voorbeelden)

Zou u hier interesse in hebben? Waarom wel/niet? Wat hindert u?

Wat is er nodig om u van gedachten te laten veranderen?

Output

Wat zijn de reststromen in uw productieproces?

Wat doet u hiermee en waarom?

Bent u bekend met de mogelijkheden van hergebruik hiervan?

Zo ja: welke?

Maakt u hier gebruik van? Waarom (niet)?

Zo ja: welke barrières bent u tegengekomen en hoe heeft u deze overwonnen?

Wat heeft u nodig om dit hergebruik nog verder te stimuleren?

Zo nee: waarom gebruikt u deze niet?

Wat is er nodig om u van gedachten te laten veranderen?

Zo nee: (benoem enkele voorbeelden)
Zou u hier interesse in hebben? Waarom wel/niet?
Wat is er nodig om uw van gedachten te laten veranderen?

4. Conditions

In de volgende vragen zou ik graag wat dieper ingaan op welke condities voor u van belang zijn voor het sluiten van materiaal- en afvalstromen middels samenwerkingen, en wanneer deze u stimuleren of juist ervan weerhouden om dit in de praktijk toe te passen.

<u>Social conditions</u>

1. In hoeverre bent u bereid om met andere partijen samen te werken om materiaalstromen te sluiten? Hoe ziet dit er idealiter uit?
2. In hoeverre is uw netwerk divers genoeg om de juiste partijen hiervoor te vinden?
3. In hoeverre bent u op de hoogte van welke partijen over de materialen beschikken die u zou kunnen gebruiken binnen de brouwerij? Hoe zorgt u ervoor dat u hiervan op de hoogte bent of hoe verkrijgt u deze informatie?
4. Welke rol speelt vertrouwen voor u in de samenwerking met andere partijen?
5. In hoeverre vindt u het belangrijk om vergelijkbare doelen en visie te hebben als uw partners? Hoe toetst u dit?

<u>Economic conditions</u>

1. In hoeverre bent u bereid om financiële investeringen te doen om uw materiaalstromen te sluiten? Wat verwacht u van de anderen/samenwerkingspartner hierin?
2. Ziet u dit als risicovol? Heeft u hiervan een voorbeeld?
3. Wat bepaalt de bereidheid om samenwerkingen aan te gaan met potentiele partners die uw restproducten kunnen gebruiken? Welke rol speelt de hoogte van afvalkosten hierin?
4. Wat bepaalt de bereidheid om samenwerkingen aan te gaan met partners wiens restproducten u kunt gebruiken? Welke rol speelt de prijs van grondstoffen hierin?

<u>Technological conditions</u>

1. In welke mate is technologie belangrijk om de kringloop te sluiten? In hoeverre beschikt u over de technologie die nodig is om op meer circulaire wijze te produceren?
2. In hoeverre verschilt de kwaliteit van alternatieve ingrediënten van de kwaliteit van reguliere grondstoffen, en hoe gaat u hiermee om?

<u>Policy conditions</u>

1. Welke rol speelt wet- en regelgeving bij uw keuze tot (meer) circulaire bierproductie?
Werkt deze bevorderend of juist beperkend? Hoe uit zich dat?
Wat doet u of uw netwerk om deze aan te passen of te beïnvloeden?
2. Heeft u voor (meer) circulaire productie extra vergunningen en certificeringen nodig, en zo ja: hoe eenvoudig of complex is het om deze te bemachtigen?

Supply chain conditions
1. Hoe heeft u het hergebruikproces ingericht? Welke afhankelijkheden zijn hierin van toepassing?
Welke rol speelt logistieke complexiteit in uw keuze om samen te werken met organisaties om materiaal- en afvalstromen te sluiten?
2. In hoeverre is de beschikbare hoeveelheid en de mate waarin u de bezorgmomenten van alternatieve grondstoffen kunt beïnvloeden voor u van belang?
Hoe stemt u dit af met anderen? Hoe kunt u elkaar hierin helpen?
3. In welke mate bent u in de gelegenheid om restproducten van uw productieproces te scheiden en op te slaan?

Afsluiting
Zijn er nog andere zaken die u relevant vindt voor dit onderzoek?

Appendix 2: Process template analysis

Motives template process

Exemplary quotes of all elements of the final templates are provided in the corresponding paragraph of the results chapter.

A priori themes:

Motives	Economic
	Policy-related*
	Ecologic

Initial template Motives

1. Ecological
   1.1. Lowering environmental impact
   1.2. Preventing unnecessary waste
2. Economic
   2.1. Reducing waste expenses
   2.2. New product opportunities
   2.3. Creating new sales channels
3. Social
   3.1. Circularity is self-evident

*Policies and legislations appeared not to be a motivation to make circular efforts.

Second template Motives

1. Ecological
   1.1. Lowering environmental impact
   1.2. Resource value retention
2. Economic
   2.1. Reducing costs
   2.2. Market opportunities
      2.2.1. New product opportunities
      2.2.2. New sales channels
      2.2.3. Stronger company story
3. Social
   3.1. Reinforcing the region
   3.2. Circularity is self-evident

Major changes in comparison to the initial template

Level added in economic dimension, new product opportunities and new sales channels are both market opportunities. Companies turn out not to make circular efforts just to save waste expenses, they also focus on reducing the operational costs by boosting the process efficiency. In addition, multiple respondents stretch out the importance of the company story in the context of differentiating from the competition, making this an economical motive, related to market opportunities. Besides, wanting to contribute to the region appears to be a reason to engage in circular practices with local companies. This is driven by their intrinsic value to help each other if possible, without demanding any compensations. Hence, the social subdimension.

Final template Motives

1. <u>Ecological</u>
    1.1. Lowering environmental impact of business activities
    1.2. Boosting resource value retention
2. <u>Economic</u>
    2.1. Reducing costs
    2.2. Gaining new market opportunities
        2.2.1. New product opportunities
        2.2.2. New sales channels
        2.2.3. Improving the company's story
3. <u>Social</u>
    3.1. Reinforcing the region
    3.2. Tracking and preventing societal harm of activities
4. <u>Policy-related</u>
    4.1. (Reducing applicable category of pollution-tax system)

<u>Major changes in comparison to the second template</u>

Every but one respondent considers sustainability and circularity as self-evident. Although this also reflects to the companies' identity, the underlying reason is actually ecological, rather than social. It is connected to the desire not to do harm to the environment or contribute to climate change. The statements coded as "circularity is part of identity" and "circularity is self-evident" only emphasizes how strong the ecological motives are embedded in the organization. Therefore, this social subdimension is removed and corresponding quotes are moved to the ecological motives section. However, there appeared an additional social motivation when applying the second template to case D. This is related to being able to see and experience the effects of the company's activities in society when collaborating with local partners. Finally, the policy motive is added, although it is only mentioned once and does not play a major role in the cases observed.

Motives coding scheme

Dimension	Theme	Sub-theme	Associated codings
Ecological	Lowering environmental impact of activities		Verlagen impact Duurzaamheid onderdeel identiteit Greenwashing
	Boosting resources value retention		Waardebehoud Weggooien is zonde
Economic	Reducing costs		Efficientie processen Besparen afvalkosten
	Gaining new market opportunities	New product opportunities	Nieuwe productmogelijkheden
		New sales channels	Versterkt afzetkanalen Verkopen elkaars producten
		Improving companies' story	Samenwerken versterkt verhaal
Social	Reinforcing the region		Versterken regio Locale samenwerkingen Ondernemers helpen elkaar
	Tracking and preventing societal harm of activities		Sociale impact Bekendheid afkomst goederen
Policy			Regelgeving belemmert circulariteit Systeem afvalbelasting

Conditions template process

A priori themes:

Social	Trust
	Willingness to collaborate
	Knowledge about other firm's resources
	Short mental distance
	Network diversity
Economic	Investment costs
	Investment and profitability risks
	Waste disposal costs
	Price of virgin materials
Technological	Availability of technological innovations
	Material quality
Policy-related	Obstructing or lacking legislations
	Difficulties to obtain permits and certifications
Supply chain	Transport complexity
	Availability and planning of received materials
	Collection and separation

Initial template conditions

1. Social conditions
   - 1.1. Willingness to collaborate
   - 1.2. Similar goals and vision
   - 1.3. Trust
   - 1.4. Informality
   - 1.5. Network diversity
   - 1.6. Knowledge of external resources
2. Economic conditions
   - 2.1. Benefiting party invests
   - 2.2. Lack of money
   - 2.3. Investment and profitability risks
   - 2.4. Waste disposal costs
   - 2.5. Price of raw resources
3. Technological conditions
   - 3.1. Complexity waste-valuation
   - 3.2. Lower quality
   - 3.3. Consistency of quality
4. Policy-related conditions
   - 4.1. Difficulty and purpose of biological certification
5. Supply Chain related conditions
   - 5.1. Transport complexity
   - 5.2. Distance
   - 5.3. Availability of planning and resources
   - 5.4. Collection and separation of waste streams

Second template conditions

1. Social conditions
   - 1.1. Willingness to collaborate
   - 1.2. Short mental distance
     - 1.2.1. Similar goals and vision
     - 1.2.2. Collaboration richness
   - 1.3. Trust
   - 1.4. Informality
   - 1.5. Insufficient network size
   - 1.6. External knowledge and interest in IS

1.7. Knowledge of external resources
1.8. Lack of time
2. Economic conditions
    2.1. Investment possibilities and willingness
        2.1.1. Willingness to invest
        2.1.2. Lack of investment possibilities
        2.1.3. Misconception about true costs
    2.2. Investment and profitability risks
    2.3. Waste disposal costs
    2.4. Price of raw resources
3. Technological conditions
    3.1. Knowledge about technological potential for IS
    3.2. Complexity of waste-valuation
    3.3. Material quality
        3.3.1. Quality of input substitute
        3.3.2. Quality consistency of alternative input
4. Policy-related conditions
    4.1. Limiting legislation
        4.1.1. Certification obligations
        4.1.2. No subsidies
    4.2. Difficulty obtaining permissions and certifications
        4.2.1. Costs of certifications
        4.2.2. Possibility to meet requirements
5. Supply Chain related conditions
    5.1. Transport complexity
    5.2. Distance of partner
    5.3. Availability of planning and resources
    5.4. Collection and separation of waste streams
        5.4.1. Possibility to separate
        5.4.2. Storage space
    5.5. Volumes of by-products

Major changes in comparison with the initial template:

Social: Similar goals and visions is mentioned as a factor obstructing IS, however, when companies have similar sustainable mindsets, a collaboration richer than just material exchange appears to be an extra enabling factor. Therefore, a short mental distance is added, and split up in both factors. Also, a (lack of) external interest in waste-exchange appears a factor which makes it difficult to find partners, and the time needed to find partners and orchestrate IS is added.

Economic: The willingness to invest replaces benefiting party invest because breweries are also willing to pay a premium when there are only ecologic benefits. Besides, a lack of money is part of financing willingness and possibilities, therefore investment possibilities added as subtheme.

Technological: Knowledge about IS possibilities added, lower quality and consistency moved to subdivision of material quality

Policy: Biological certifications have more to do with sustainability than IS, making it less relevant. However, waste exchange requires other certifications. These are difficult to obtain, costs and possibility to meet the requirements added. No subsidies added, not targeted at small companies due to low number of employees.

Supply chain: possibility to separate added, some hops cannot be separated. Storage space added as part of collection and separation. Volumes of by-products added, breweries have insufficient volumes for commercial use.

Final template conditions

1. Social conditions
    1.1. Willingness to collaborate
    1.2. Short mental distance
        1.2.1. Similar goals and vision
        1.2.2. Collaboration richness
    1.3. Trust
        1.3.1. Informal agreements based on trust
        1.3.2. External lack of trust in receivers' intentional use
    1.4. Network diversity
        1.4.1. Insufficient network diversity/size
        1.4.2. Value of existing communities
    1.5. External interest in IS
        1.5.1. Lack of external willingness/motivation to close loops
        1.5.2. No dedicated initiatives aimed at breweries
    1.6. Knowledge of external resources
    1.7. Time
        1.7.1. Time available
        1.7.2. Willingness to invest time in waste streams

2. Economic conditions
    2.1. Investment possibilities and willingness
        2.1.1. Willingness to invest
        2.1.2. Lack of investment possibilities
        2.1.3. Misconception about true costs
    2.2. Investment and profitability risks
    2.3. Waste disposal costs
    2.4. Price of raw materials
    2.5. Compensation for by-product exchange

3. Technological conditions
    3.1. Knowledge about technological potential for IS
    3.2. Technological complexity of IS
    3.3. Material quality
        3.3.1. Quality of input substitute
        3.3.2. Quality consistency of alternative input
        3.3.3. Material composition of alternative input

4. Policy-related conditions
    4.1. Limiting legislation
        4.1.1. Food waste-to-resource practices require certification
        4.1.2. Applicability of stimulating policies
    4.2. Difficulty obtaining permissions and certifications
        4.2.1. Costs of certifications
        4.2.2. Possibility to meet requirements

5. Supply chain related conditions
    5.1. Transportation complexity
        5.1.1. Distance of partner
        5.1.2. Responsibility of transport
    5.2. Availability of planning and resources
    5.3. Collection and separation of waste streams
        5.3.1. Possibility to separate
        5.3.2. Storage space
        5.3.3. Perishability
    5.4. Volumes of by-products

Major changes in comparison with second template

Social: Informality is related to the way agreements are made, and is therefore part of trust. External lack of trust in receivers intentional use added. Value of existing communities added as part of network diversity. External knowledge and interest in IS divided in external willingness/motivation and lack of existing initiatives added.

Economic: The compensation for waste-exchange added.

Technological: Material composition of alternative input added

Policy-related: No subsidies changed in applicability of stimulating policies because tax benefits are also part of it.

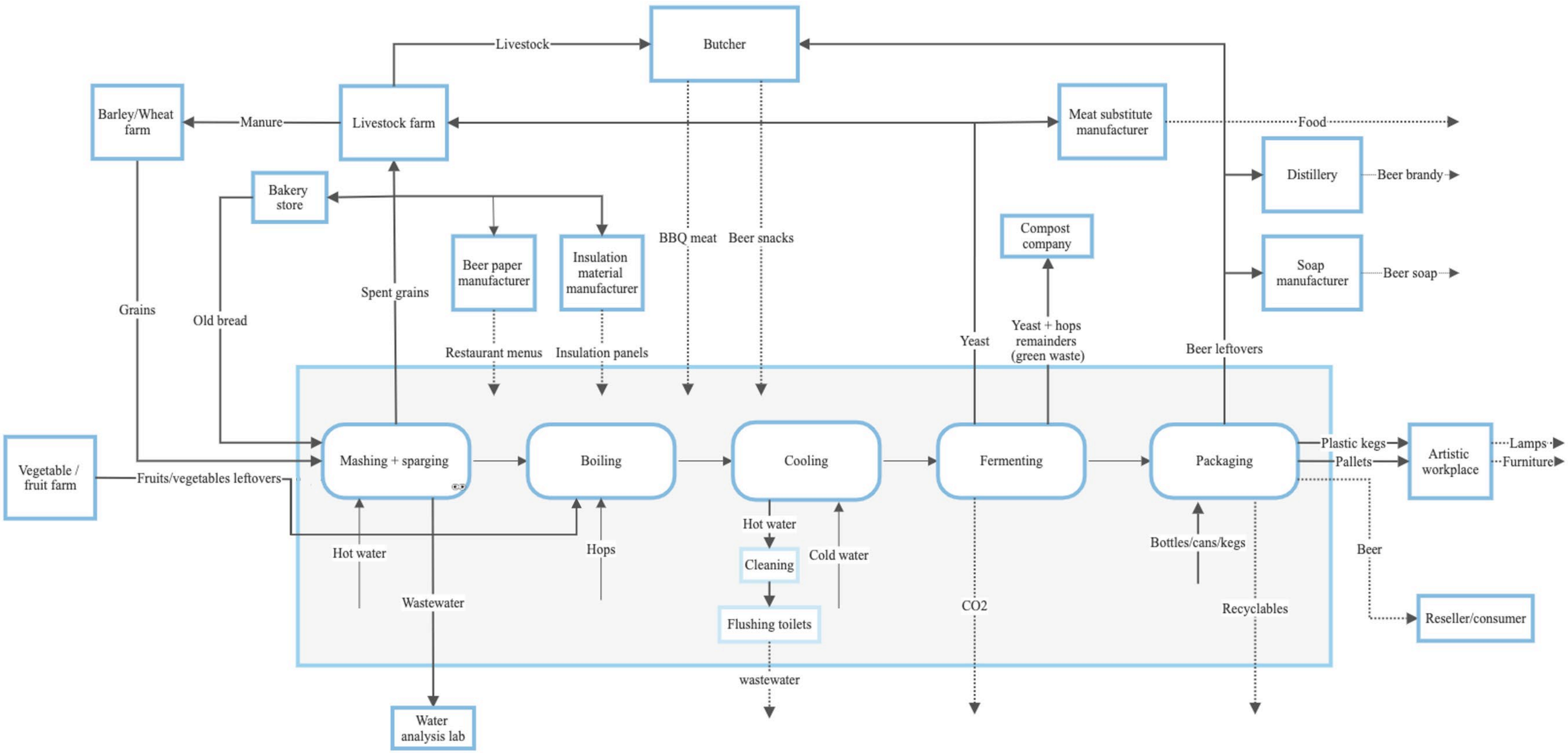
Supply chain: Distance of partner is part of transport complexity, responsibility of transport added. Perishability added since spent grains have to leave the brewery within 24h, or need cooling.

Conditions coding scheme

Dimension	**Theme**	**Sub-theme**	**Associated codings**
Social	Willingness to collaborate		Bereidheid samenwerking
	Short mental distance	Similar goals & Vision	Zelfde doelen Vergelijkbare merkwaarden Langdurige samenwerking
		Collaboration richness	Gezamenlijk uitdragen verhaal
	Trust	Informal agreements	Informele afspraken Eenvoud samenwerkingen Afspraken op vertrouwen Betrouwbaarheid
		External lack of trust in receivers intentional use	Bang voor misbruik reststroom
	Network diversity	Insufficient network diversity/size	Netwerk te klein Kent niet de juiste partijen Faciliteren/coordineren
		Value of existing communities	Voordelen bestaande netwerken Sterke banden in gemeenschap
	External interest in IS	Lack of external willingness/motivation to close loops	Lage externe interesse Moeilijk te overtuigen Geen reactie meer
		No dedicated initiatives aimed at breweries	Te weinig initiatieven voor hergebruik reststroom
	Knowledge of external resources		Restanten bij toeval tegengekomen Zelf op zoek naar restanten Restpartij aangeboden
	Time	Time available	IS kost veel tijd Te druk met dagelijks werk
		Willingness to invest time in waste streams	Tijd willen investeren
Econ	Investment possibilities and willingness	Willingness to invest	Bereidheid investeringen Bereidheid meerprijs
		Lack of investment possibilities	Gebrek aan kapitaal Investeringsmogelijkheden
		Misconceptions about true costs	Ketens sluiten hoef niet duur te zijn
	Investment and profitability risks		Terugverdientijd Economisch rendement niet belangrijkst
	Waste disposal costs		Afvalkosten

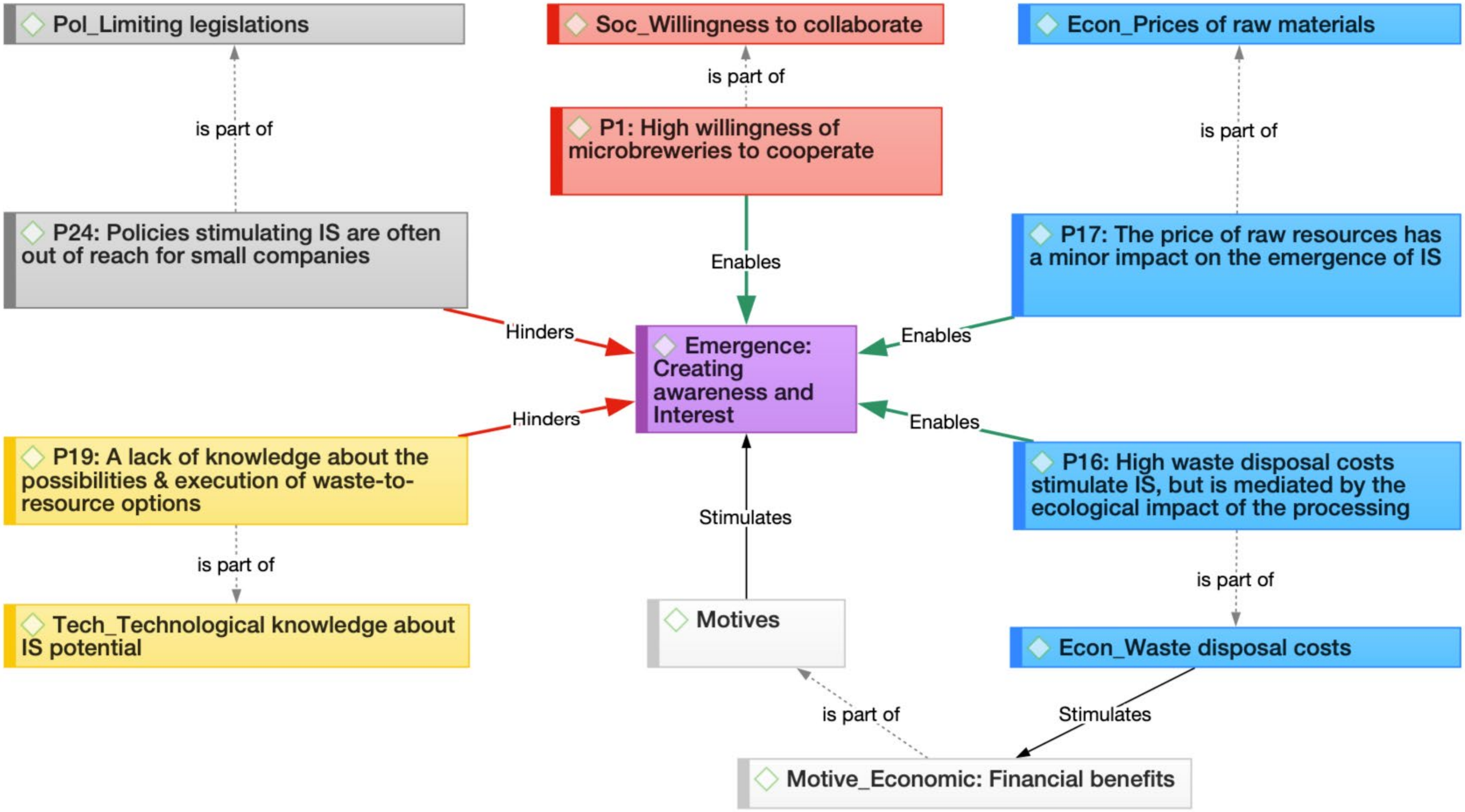
			Meerprijs duurzame afvalverwerking
	Prices of raw materials		Grondstofprijzen
	Compensation for by-product exchange		Reststroom vergoeden in bier Vergoeding reststroom Alleen verdienen op eigen core activities
Tech	Knowledge about tech. potential IS		Beperkte kennis mogelijkheden IS Beperkte kennis verwerking restproducten
	Tech. complexity of waste-valuation		Probleem filtersysteem Open brouwhuis
	Material quality	Quality of input substitute	Kwaliteit restproducten
		Quality consistency of input	Constante kwaliteit
		Material composition of input	Onbekende samenstelling reststroom
Policy	Limiting legislations	Food waste-to-resource practices require certification	Belemmering benodigde certificeringen
		Applicability of stimulating policies	Subsidies gericht op grote bedrijven Fiscaal Te klein voor belastingvoordeel
	Difficulty obtaining permissions/certifications	Costs of certifications	Certificering duur op kleine schaal Certificeren kost veel tijd
		Possibility to meet requirements	Voldoen aan regels moeilijk Hele keten moet gecertificeerd zijn
SC	Transport complexity	Distance of partner	Korte afstanden transport Duurzaamheid transport
		Responsibility of transport	Ontvanger verantwoordelijk voor vervoer
	Availability of planning and resources		Wisselend aanbod Veel brood beschikbaar Dezelfde dag ophalen
	Collection & separation of waste streams	Possibility to separate	Scheiden reststroom
		Storage space	Beperkte opslag
		Perishability	Beperkte houdbaarheid
	Volumes of by-products		Te laag volume hergebruik Kleine hoeveelheden reststromen

Appendix 3: Overview of IS possibilities based on results

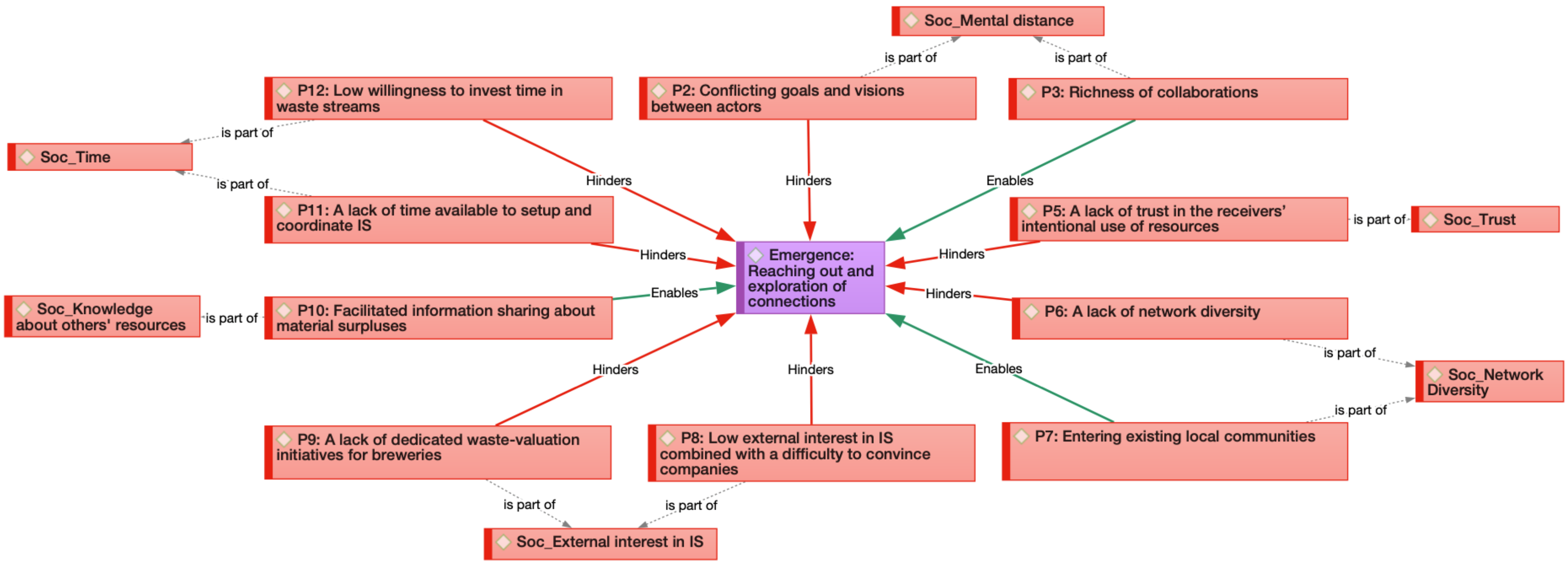


Appendix 4: Relation between conditions and IS Emergence activities

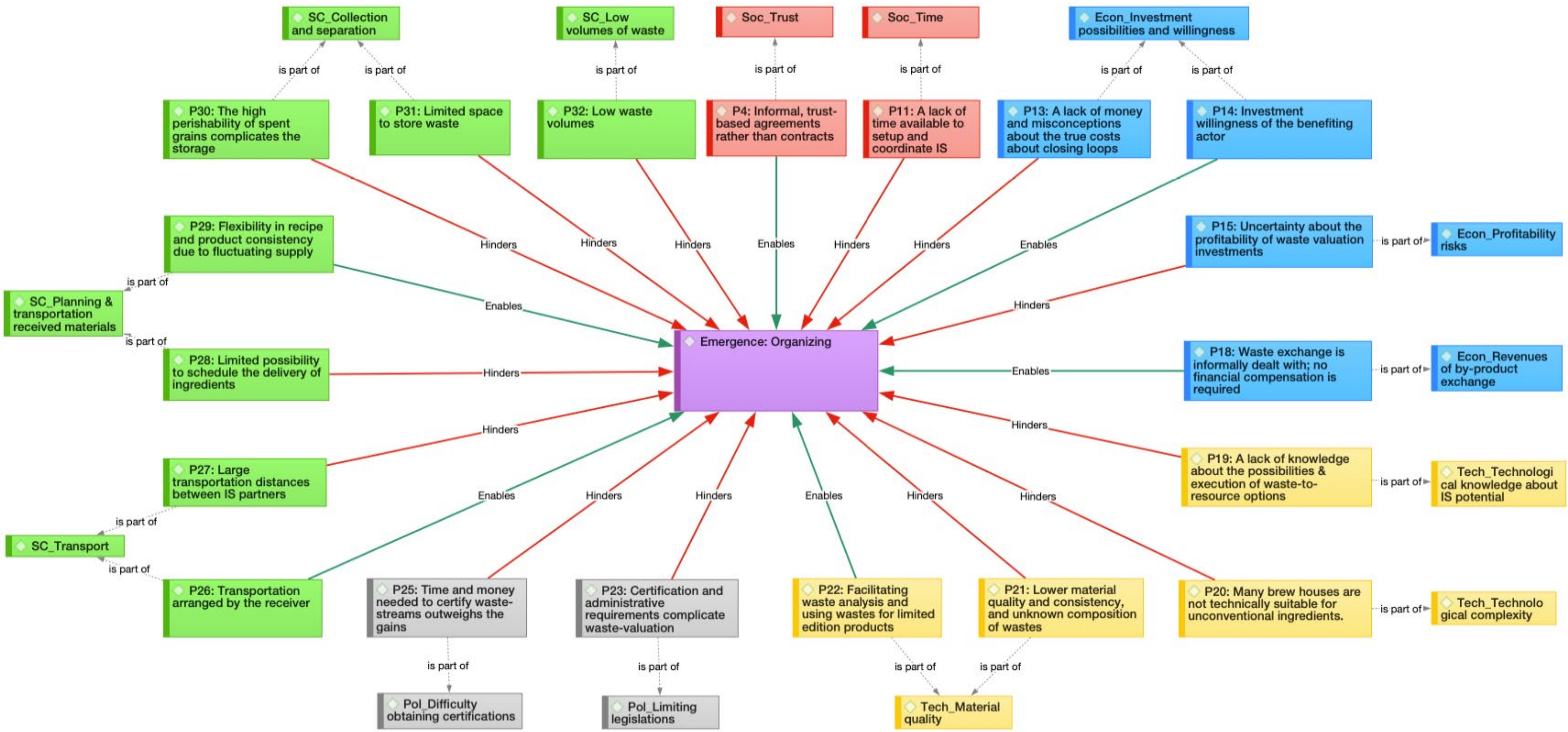
Creating Awareness and Interest



Reaching out and Explorations of Connections



Organizing


SC_Collection and separation
SC_Low volumes of waste
Soc_Trust
Soc_Time
Econ_Investment possibilities and willingness
P30: The high perishability of spent grains complicates the storage
P31: Limited space to store waste
P32: Low waste volumes
P4: Informal, trust-based agreements rather than contracts
P11: A lack of time available to setup and coordinate IS
P13: A lack of money and misconceptions about the true costs about closing loops
P14: Investment willingness of the benefiting actor
P29: Flexibility in recipe and product consistency due to fluctuating supply
P15: Uncertainty about the profitability of waste valuation investments
Econ_Profitability risks
SC_Planning & transportation received materials
Emergence: Organizing
P28: Limited possibility to schedule the delivery of ingredients
P18: Waste exchange is informally dealt with; no financial compensation is required
Econ_Revenues of by-product exchange
P27: Large transportation distances between IS partners
P19: A lack of knowledge about the possibilities & execution of waste-to-resource options
Tech_Technological knowledge about IS potential
SC_Transport
P26: Transportation arranged by the receiver
P25: Time and money needed to certify waste-streams outweighs the gains
P23: Certification and administrative requirements complicate waste-valuation
P22: Facilitating waste analysis and using wastes for limited edition products
P21: Lower material quality and consistency, and unknown composition of wastes
P20: Many brew houses are not technically suitable for unconventional ingredients.
Tech_Technological complexity
Pol_Difficulty obtaining certifications
Pol_Limiting legislations
Tech_Material quality
is part of
Hinders
Enables

Full overview emergence activities