Tecnun
Universidad
de Navarra

Pº Manuel Lardizabal, 13.
20018 Donostia-San Sebastián, Spain
Tel.943 219 877
Fax 943 311 442
www.tecnun.es

VNIVERSITAS STVDIORVM
NAVARRENSIS VNIVERSITA
AS STVDIORVM NAVARRENS

A TRANSITION MANAGEMENT METHODOLOGICAL FRAMEWORK TOWARDS AN INDUSTRIAL SYMBIOSIS WITHIN A CIRCULAR ECONOMY

John Anderson Rincón Moreno

A transition management methodological framework towards an industrial symbiosis within a circular economy

DISSERTATION
submitted for the Degree of Doctor of Philosophy from Universidad de Navarra by

John Anderson Rincón Moreno

under the supervisión of

Dr. Marta Ormazábal Goenaga y
Dr. María del Carmen Jaca García

Donostia-San Sebastián, October 2022

Tecnun
Universidad
de Navarra

UNIVERSIDAD DE NAVARRA

ESCUELA DE INGENIERÍA

Tecnun
Universidad
de Navarra

A transition management methodological framework towards an industrial symbiosis within a circular economy

DISSERTATION

submitted for the Degree of Doctor of Philosophy by

John Anderson Rincón Moreno

under the supervision of

Dr. Marta Ormazábal Goenaga and

Dr. María del Carmen Jaca García

Donostia-San Sebastián, October 2022

Mucha gente pequeña, en lugares pequeños, haciendo cosas pequeñas,
puede cambiar el mundo.

Eduardo Galeano.

Acknowledgements

"It ain't over 'till it's over" es una frase que suelo repetir cuando aún falta el último reto para finalizar un objetivo. Todo empezó en el 2008 cuando fui invitado a participar en un proyecto de investigación en energías renovables. Aunque tenía pocas certezas de que la investigación fuese mi futuro, estaba 100% seguro y, lo sigo estando, que la curiosidad y la pasión de trabajar por algo en lo que creo son mi compás en la vida. Han pasado ya 14 años desde aquella invitación, pero hoy más que nunca el "It ain't over 'till it's over" se siente real, ya casi. Aunque quisiera agradecer a muchas personas, me concentraré en los últimos 4 años de vida que me han traído hasta este punto.

Primero, quisiera agradecer a las M&Ms. Marta, gracias por creer en mí, por tu paciencia y ser ese "pain in the ass" que le hacía falta a mi vida profesional. Tu inteligencia, tus observaciones y tu incansable dedicación a tu trabajo me han servido de ejemplo y de inspiración en esta etapa. Tu "no me convence" y tu exigencia me convirtieron en un mejor profesional, ya que me hicieron romper esas barreras mentales que limitan nuestro verdadero potencial y crecimiento. Mentxu, gracias por aportar ese pragmatismo a mi vida profesional que me ha

enseñado que este mundo le pertenece a los que actúan. Tu asertividad me ha ayudado inmensamente a combatir mi dispersión mental, que muchas veces te hacía poner esa cara de desconcierto e inquietud. Asimismo, tu liderazgo y tu empatía son tesoros y aprendizajes que llevaré conmigo siempre, mila esker. M.J., a pesar de no ser mi supervisora, siempre estuviste allí con un consejo, una anécdota o alguna solución. Tu buen humor y tu buena actitud me contagiaron durante todo el proceso, gracias.

Sarri (Q.E.P.D), Álvaro, Eli, Javi, Josune, Leire, Marcos y Nico gracias por estar ahí, siempre disponibles para resolver una duda por más pequeña que esta fuera, por compartir anécdotas, chistes y cafés durante este tiempo. La experiencia de ustedes es invaluable para cualquier doctorando.

JFCA y Ferdinand III, no logramos 99 pintxos, pero logramos momentos memorables en una etapa especial de nuestras vidas que espero continúen. Gracias mis tálpidos por las conversaciones serias y las no tan serias que ayudaron a replantearme conceptos, tanto en la vida como en la tesis.

Cinta y Marta, gracias por ser como son y ayudarme a ver con otra perspectiva las cosas realmente importantes en la vida. Eskerrik asko.

My Little Flower, gracias por ser como eres. Tu apoyo incondicional en alguna etapa de la tesis fue fundamental para sacar cosas adelante. Tu colaboración desinteresada es una muestra de las cualidades que te hacen especial como persona y que siempre valoraré de tu amistad. Espero prestarte mi apoyo total como tú lo has hecho conmigo.

Dear Sahar, thank you for your unexpected friendship. Our endless conversations that you always started made my life easier when I needed the most. Your insights were also pivotal at one point in my thesis, and I will never forget them. I hope to keep building our friendship around your relentless bullying that makes me resilient, like a phoenix. Shukran

Anne, thanks for helping me a lot during the last stretch of my PhD. Your brightness exceeded my expectations, and your kindness and straightforwardness have been the highlights of my visit research. Dankjewell.

Jorge, Mónica y Laura, gracias por su amistad y por estar siempre allí a una llamada o a un mensaje de distancia para resolver mis dudas más cruciales.

A Mila, Willy, Daniel, Darwin, Méndez y demás amigos, gracias por ofrecerme esa amistad incondicional.

Ata, Pini y BB, gracias por ser esas hermanas que la vida me dio y por ser mis más fervientes fanáticas. Al resto de mi familia, que me han apoyado siempre, gracias.

A mis dos papás, Luciano y Luis, gracias por enseñarme que la educación es el regalo más importante que me han podido dejar. Pa, gracias siempre por impulsarme a intentar nuevos retos y por ser mi ejemplo y apoyo más racional. Abuelo, aunque ya no estés en este mundo, quisiera decirte que se te van a cumplir dos de tus deseos; ya tienes a un ingeniero y próximamente a un doctor. Gracias por enseñarme los valores más importantes en la vida. Ojalá hayas entendido el impacto positivo que tuviste en mí.

Mita, gracias por ser mi consejera, amiga, y mamá favorita. Tal vez, la nobleza de tus actos y la bondad con las que tratas a las demás personas han sido las razones definitivas por las que me he inclinado por trabajar en tener un lugar más justo social y ambientalmente. Gracias por motivarme a intentar cosas nuevas a pesar de tus preocupaciones, exigirme siempre a ser una mejor persona y por siempre, siempre estar ahí.

Abuelita, gracias por enseñarme a amar la Pachamama, ojalá estuvieras aquí para ver a tu nieto contestón intentar ser doctor.

Y por supuesto, Cocky. Amor para todas y todos.

Por último, un agradecimiento al Departamento de Medio Ambiente y Obras Públicas de la Diputación Foral de Gipuzkoa, que ha financiado parte de esta tesis doctoral mediante los convenios firmados con Tecnun, eskerrik asko.

Eso es todo, por ahora, ya veremos cuál será mi próximo "It ain't over 'till it's over". Disfruta la lectura de la tesis, si te apetece, sin compromiso ¡Agur!

OUTLINE

FIGURES

TABLES

Abstract

As industries are reasonably accountable for depleting resources, they play a pivotal role in socio-technical systems (e.g. energy, food system, transportation) between the business environment and the wider environment to achieve a sustainable model. Nevertheless, the current production pattern is based on a model of take-make-dispose or better known as a linear economy, that is no longer sustainable over time. This linear model is considered a wasteful system as it allows goods to lose value during their life cycle.

Some solutions focused on solving this issue have been developed in recent decades so as the circular economy (CE) to counteract this problem. Hence, industrial symbiosis (IS) is portrayed as one solution for the environmental impact of this polluting approach and has been a subject of study since the 90s. So, IS may be seen as a subset of a CE where business model innovation results from technical innovations by exchanging waste, resources, and energy through collaboration with stakeholders to accelerate a CE implementation. The IS aims to keep the value of materials as long as possible by creating a closed loop system whereby goods may recover some of their value during their lifecycle.

However, to move away from a linear model to a model that recirculates materials, it is necessary to facilitate the transition towards this new model. Therefore, a successful transition to a CE model would need IS research to explore ways to organise industries beyond highly technical factors that guide the coalition of stakeholders to create new value for businesses and society. This transition might be accomplished by bringing stakeholders from all backgrounds to jointly build a new approach to controlling a complex environment and its role.

Most approaches to developing strategies, providing solutions, and integrating collective learning have fallen short of realisation. Some authors have argued that it is essential to encourage stakeholders to increase the uptake of this new model. There is a misunderstanding about how many stakeholders might approach and affect the needed adjustments to support a transition. Thus, this thesis seeks to make the transition process easier by detailing how the transition governance model may be managed to produce new value for enterprises and society.

As a result, this thesis proposes a TM methodological framework that aids the CE transition process via IS. The ideas of the TM framework were utilised to analyse IS systems, and the four cycles of the TM framework were used to study processes in two areas. The transition to a CE framed within an IS system may be regulated if the TM framework is viewed as a helpful facilitation guide. As a result, the evidence presented in this thesis is followed, which would aid the transition process.

It is intended that this thesis has thrown light on the lack of knowledge of how many stakeholders may address and influence desired changes in the face of escalating environmental and social challenges, which prompted the start of a transition process. A strong emphasis on proactive management, such as establishing inter-organisational strategies and managing multiple types of stakeholders in a way that considers them all together, might assist the progress of the transition.

1 Introduction

This section presents the theoretical basis on which the thesis has been developed. It also introduces IS and how it is understood in a CE context for this thesis. Then, the problem that has motivated the development of this thesis is presented. Also, the research questions, the objectives and the publications achieved during this thesis are presented. Finally, a summary of the chapters that are part of the thesis development is given.

1.1 Background information

Industries are mainly responsible for the world's use of resources and generating waste, thereby accounting for polluting and harming the environment (Prieto-Sandoval et al., 2019). The worldwide waste and resources industry has generally been considered a laggard in improving sustainability. In Europe alone, companies could be responsible for causing nearly 64% of industrial pollution (European Commission, 2010). This trend lies in the traditional linear economy model that reigns this system, focusing on endlessly taking up virgin resources, making products, and disposing of them as waste in landfills (Prieto-Sandoval, Jaca, et al., 2018).

Nonetheless, industrial systems have attempted to achieve sustainability through different adaptations and reformations, whether through resource optimisation at the input stage or effective waste management at the output stage (Gopinath et al., 2018). Moreover, in recent years, the industrial system has been recognised as playing an essential part in sustainability transitions related to practises based on the CE, in which wastes are viewed as resources (Aid et al., 2017; Geissdoerfer et al., 2017). With a wide range of technologies to select from and increasing pressure to be environmentally responsible, enterprises are gravitating toward the notion of lessening new materials and energy consumption under a CE system (Herczeg et al., 2018).

The CE is a paradigm shift aimed at preventing the exhaustion of resources by closing energy and materials loops (Prieto-Sandoval, Jaca, et al., 2018). The applicability of CE is rooted in different schools of thought that, taken together, shape the idea of closed loops (Geissdoerfer et al., 2017). Several authors have listed the most renowned schools of thought that refine the practical applications of the CE, such as cradle to cradle, industrial ecology, biomimicry, performance economy and regenerative design (Ellen MacArthur Foundation, 2013; Graedel & Allenby, 2010; Homrich et al., 2018; Janine, 2002; Lyle, 1996; McDonough & Braungart, 2010; Stahel, 2010).

In particular, industrial symbiosis (IS), a sub-research field of industrial ecology, has been described as an approach to CE implementation due to its

capacity to spur companies' growth while dealing with natural resource depletion (Daddi et al., 2017; Martín Gómez et al., 2018; Saavedra et al., 2018; Winans et al., 2017). Likewise, IS is governed by the CE principles that strive to transform the effects of the linear model into positive environmental impacts. IS enforces an approach that takes inspiration from how industrial systems mimic natural ecosystems and can simulate the distribution of materials, energy, and information flows (Mallawaarachchi et al., 2020).

The most widely known definition is given by Chertow (2007), who described IS as a system that gathers distinct industries in a joint approach to gain a competitive advantage by linking the physical exchanges of resources in a context where cooperation and synergistic opportunities offered by geographic proximity are significant. The proximity between companies is regarded as a critical component, as it facilitates the sharing of supplies and reduces transportation costs (Chertow & Ehrenfeld, 2012; Schiller et al., 2014). Taking the particular features of IS, authors such as Domenech et al. (2019) pointed out that a common characteristic of IS is the diversity of sectors and stakeholders involved and the multiple opportunities that could be created across value chains in diverse industrial sectors to transition towards a CE.

A successful transition to a CE model driven by IS would finally close the loop by decreasing resource depletion and minimising waste from the industrial system (Domenech et al., 2019; Ghisellini et al., 2016). Nevertheless, a lack of a system perspective regarding transitioning toward a CE has been an obstacle (Fraccascia et al., 2019). Some obstacles are related to unspecified roles, lack of a social coordination model and low levels of a broad collaboration of stakeholders (Millar et al., 2019). Consequently, the transition towards a local CE system requires that the interests of multiple stakeholders within the value chain be aligned to achieve a circular solution (European Commission, 2019).

1.2 Importance of the IS towards a CE transition

From the standpoint of CE, IS is a business model archetype based on sharing infrastructures and by-products to increase resource efficiency and

produce value from waste (Baldassarre et al., 2019). IS aids in the transition to a CE by minimising dependency on virgin resources (Abreu & Ceglia, 2018; Nasir et al., 2017; Saavedra et al., 2018). According to Abreu & Ceglia (2018), implementing the CE through IS initiatives is critical to engaging corporate and non-business actors to achieve complex synergies. Collaboration amongst stakeholders such as enterprises, governments, and institutions in an IS may enable the transition to a CE (Saavedra et al., 2018).

So far, as some authors have argued (Ghinoi et al., 2020), encouraging other stakeholders to increase uptake of this new model among companies, cooperation between stakeholders becomes pivotal to allow for the transformation towards a circular model (Xiang & Yuan, 2019). Esposito et al. (2018) and Mortensen & Kørnøv (2019) highlight the significance of dealing with different stakeholders to facilitate the adoption of IS to promote agreements.

Similarly, Aid, Eklund, Anderberg, & Baas (2017a) address the role of waste management organisations in creating value in an IS network to determine potential opportunities within a CE. The authors supported that waste management companies should use the inter-organisational resource network as a model for IS development. Authors such as Gopinath et al. (2018) backed this idea by creating a symbiotic framework with primary and secondary sugar industry waste as feedstock for energy production and construction products. They emphasised that developing long-term relationships is critical for addressing uncertainties in adopting this type of IS network.

However, realising the promise of IS is not a straightforward path, and it seldom happens quickly (Álvarez & Ruiz-Puente, 2017; Walls & Paquin, 2015). Some reasons for lagging in implementation are attributed to a hesitant industry ecosystem willing to embrace the transition (Kirchherr et al., 2018). In some cases, the problem of transitioning to a CE via implementing IS is primarily attributed to the complexity of making fundamental changes at the organisational and operational levels (Manninen et al., 2018). Progress in IS is also hampered by a lack of information and awareness among essential players (Hein et al., 2017). Data about the quantity and location of input materials and

waste streams of the relevant geographical region are hurdles to creating IS networks.

Consequently, IS deployment in some industries is unknown, despite being demonstrated as a potential strategy to promote the CE transition (Y. Yu et al., 2021). Furthermore, experimental cases showing performance are not a widely extended practice (Kalmykova et al., 2018). CE has primarily shaped waste management and recycling practices (Winans et al., 2017), while IS practices such as reusing or upcycling remain niche phenomena (Ghisellini et al., 2016). Such a low level of IS implementation is a drawback to the advancement of the CE (Panwar & Niesten, 2020).

Consequently, a systematic approach that considers the many system components and their interactions are necessary for implementing IS (Kern et al., 2020). So, to foster IS and contribute to creating a fair playing field across industries, IS will demand some level of shared strategic visions and collaborative decision-making that nowadays are missing (Herczeg et al., 2018; Vanhrevolutiont al., 2020). In this context, it is critical to encourage symbiotic industrial alliances, in which businesses employ waste products from other industries as raw resources (Gopinath et al., 2018). Palm & Karolina (2021) suggest that encouraging symbiotic industrial alliances with different actors, such as local governments, should establish a clear strategy for IS. Thus, governance mechanisms and the interweaving of meanings associated with IS will be crucial in influencing the direction and rate of development (Flynn et al., 2019).

1.3 Governing the transition

The conflicts around CE implementation are seldom linked to types of governance (Mathews et al., 2018). In that sense, the literature has reported adopting a system perspective rather than a firm stand to implement IS business models focused on the system's governance and the stakeholders involved in that circular system (Fraccascia et al., 2019). Such governance models also give normative direction to influence transitions (Flynn et al., 2019). In particular,

Fraccascia et al. (2019) suggest that from a strategic standpoint implementing IS shall be more about structure and management in the form of governance. According to Velenturf (2016a), it would be beneficial to enable learning among governmental bodies and other stakeholders while governing in a flexible and adaptable way via network steering, which involves collaborations between state- and non-state stakeholders.

So, it is critical to emphasise the significant role of major stakeholders, and their expectations for CE practises such as IS in governance and the transition process itself. This CE practises a change in emphasis to the specifics of how transitions occur to understand better how it operates in reality (Flynn et al., 2019). One approach to deal with this issue refers to network governance. The phrase refers to the process of social coordination among public and private players participating in the formulation and execution, in which network interactions influence substantive results (E.-H. Klijn & Koppenjan, 2012).

Network governance creates the space for engagement and multi-sectoral collaboration among various organisations; they facilitate informed decision-making based on knowledge exchange and deliberation among interdependent stakeholders; and they foster engagement to achieve negotiated goals (E. H. Klijn & Koppenjan, 2015). One of the models of governance networks that aim to serve as social coordination systems and seek the interaction of multiple actors to make sustainability transitions manageable in social environments is called transition management (TM) (E. H. Klijn & Koppenjan, 2015). The TM model expressly attempts to leverage the possibilities of network governance to assist transitions in today's complex social systems, such as the CE (Nochta & Skelcher, 2020).

1.4 Problem statement

Although CE implementation is still in its early stages, the concept has begun to drive behaviour toward more sustainable production patterns (Lewandowski, 2016). As the previous sections explain, the IS can help facilitate a transition towards a more "circular" production system. This transition will require a systemic change in how the IS has been conducted. Thus, it will need

to work with stakeholders on ways to develop governance that facilitates the transition. This sort of focus on a system perspective would help to understand how IS networks are incentivised to change through different stakeholders' interests (Yuan et al., 2019). Various views covering all stakeholders involved in ensuring a transition towards a CE remain a subject of study (Abreu & Ceglia, 2018; Millar et al., 2019).

In this regard, Mortensen & Kørnøv (2019) highlight the relevance of dealing with different stakeholders to generate organisational designs that facilitate the adoption of IS, such as policies to promote agreements. Velenturf (2017) calls for understanding how IS develops and can be enabled by public and private partners, which is still limited thus far. Other studies have emphasised the relevance of local governments organising, planning, and implementing IS initiatives through better governance (Cerceau et al., 2014; Yuan et al., 2019). In this way, the governance of the CE system would impact how businesses develop and capture value through the use of IS (Fraccascia et al., 2019).

By ignoring the relevance of the governance network in an IS, implementing CE would be limited to value creation and value capture from waste. This creation and capture of value through IS demand increasing coordination to confront organisational obstacles and several actions with stakeholders must be organised to carry out the transition (Bansal & McNight, 2009; Herczeg et al., 2018). Especially IS within a CE where enterprises are integrated into a sophisticated network of IS linkages involving a wide range of participants (i.e., government, social actors, facilitators, and firms).

However, most studies in the literature fail to discuss the potential of going circular through IS by detailing the steps to go from this rhetoric to implementation (Fraccascia et al., 2019). Cases describing the creation of symbiotic networking strategies in the regions are among the gaps in the literature that should be filled (Cramer, 2020c). Turken & Geda (2020) find that network coordination is the least examined among scholarly publications on tactical decisions in symbiotic relationships. Thus, it is essential for research that is centred on governing the transition process to fundamentally guide the

coalition of stakeholders to create new value for businesses and society (Loorbach & Wijsman, 2013).

1.5 Research questions, objectives, and publications

The success of transitioning towards a circular system to create value from IS networks is decided at the group level (Derks et al., 2022). This transition must be done by bringing together stakeholders from different backgrounds to collectively develop a new way of governing a complex environment. However, a lack of understanding and studies reflects how multiple stakeholders should approach and act to influence the desired changes to facilitate a transition. Thus, the research questions this thesis aims to answer are the following:

RQ How can the transition be governed towards an IS?

SRQ1. Who are the stakeholders that should guide the transition?

SRQ2. What are the strategies that should be implemented?

SRQ3. What are the actions needed to achieve those strategies?

SRQ4. How can the transition be monitored?

To answer these research questions, the main objective of this thesis is to facilitate the transition process by describing how the transition can be managed to create new value for businesses and society. Thus, this thesis presents a TM methodological framework that supports the CE transition process through IS. In detail, the research objectives are the following:

- ✓ Objective 1: Identify the **key stakeholders and their roles** in supporting the transition.
- ✓ Objective 2: Determine the **strategies** required to transition towards an IS within a circular economy
- ✓ Objective 3: Identify stakeholders' actions to develop a transition process.
- ✓ Objective 4: Determine the **approach** to track progress on the transition

It is worth mentioning that the thesis results are gathered from five journal publications and five conference proceedings. Table 1 summarises the contribution of each journal or conference publication to both the research questions and objectives. The journal publications are P1, P2, and P3 and conference proceedings as C1, C2, C3 and C4. Further detail on the publications is given in the last chapter of this document.

- P1. Rincón-Moreno, J., Ormazabal, M., Álvarez, M. J., & Jaca, C. (2020). Shortcomings of transforming a local circular economy system through industrial symbiosis: a case study in Spanish SMEs. *Sustainability*, *12*(20), 8423.
- P2. Rincón-Moreno, J., Ormazábal, M., & Jaca, C. (2021). Stakeholder perspectives in transitioning to a local circular economy: a case study in Spain. *Circular economy and sustainability*, 1-19.
- P3. Rincón-Moreno, J., Ormazábal, M., Álvarez, M. J., & Jaca, C. (2021). Advancing Circular economy performance indicators and their application in Spanish companies. *Journal of Cleaner Production*, *279*, 123605.
- P4. Rincón-Moreno, J., Ormazabal, M., Álvarez, M. J., & Jaca, C. (2022). Industrial symbiosis strategies for transitioning towards a circular economy: perspectives from Spanish stakeholders. *(Minor revision)*.
- P5. Rincón-Moreno J., Orjuela-Garzón W., Jaca C, Ormazábal M. (2022). Insights for a transition towards a circular economy through industrial symbiosis. *(Under review)*.
- C1. Rincón-Moreno, John, Jaca, Carmen, Álvarez, María Jesús, Ugartemendia, Pedro, Ormazabal, Marta (2020). Analysis of industrial waste management regulation to drive resource management in a circular economy: a case study in Spain. In: 26th Annual International Sustainable Development Research Society **Conference** 15-17 July 2020, Budapest, Hungary.
- C2. M. Ormazabal, F. García, C. Jaca, J Rincón-Moreno, and M. J. Alvarez (2021). Fostering IS. Potential drivers and barriers. In: Proceedings of the 15th International Conference on Industrial Engineering and Industrial, 8-9 July 2021, Burgos, Spain.

- C3. Rincón-Moreno J, Ormazabal M, Alvarez M.J, Jaca C. (2021). CE implementation strategies towards circular economy operationalisation: transition perspectives from the meso-level in Spain. In: 27th Annual Conference, International Sustainable Development Research Society, 13–15 July 2021, Östersund, Sweden.
- C4. Rincón-Moreno J, Velenturf A, Jaca C, Ormazabal M. A transition methodology framework towards a circular economy in industrial contexts: reflections on the Humber Region scenario. (2022). In: 28th Annual Conference, International Sustainable Development Research Society, 15-17 June 2022, Stockholm.

Table 1. Contribution of the publications to the research

Research question (RQ), sub-research question (SRQ) and objectives (O)	**P1**	**P2**	**P3**	**P4**	**P5**	**C1**	**C2**	**C3**	**C4**
RQ	X	X	X	X	X	X	X	X	X
SRQ1	X	X							X
SRQ2				X					X
SRQ3								X	X
SRQ4			X						X
O1	X	X				X			X
O2								X	X
O3								X	X
O4			X						X

1.6 Chapter overviews

The chapters of the thesis are structured in the following way:

- Chapter 2 presents the state-of-the-art concerning IS, circular economy, and sustainability transitions. It first gives an overview of the definition, barriers, and contribution of IS, the purpose of CE and their contribution towards sustainable production. Then, it presents how sustainability transition has been defined in the literature.
- Chapter 3 explains the different phases of the research methodology followed to develop a Transition Management methodological framework.
- Chapter 4 presents the development of the transition management methodological framework. This section describes the paths, stakeholders, roles, strategies, and experiments that compose the framework.
- Chapter 5 discusses the TM framework results, how the methodological framework shall be used, and by whom.
- Chapter 6 explains the verification phase of the research to ensure the usefulness and relevance of the Transition Management methodological framework.
- Chapter 7 summarises this research's main conclusions and limitations and proposes ideas for further investigation.

2 Literature review

This section presents the main findings in the literature that show how the evolution of IS within a CE context needs to explore other theories that have not received much attention and application in this field, such as transition studies.

First, an introduction to IS is given where the context and theoretical basis are mentioned, with case studies and examples found in the literature. Then, the barriers and drivers that have hindered or facilitated the implementation of IS in the literature are listed. Then, solutions presented in recent literature to facilitate IS implementation and how transition studies, especially the transition management framework, offer a theory that could help consolidate an approach to move away from linear production. Finally, the main contribution of this research is presented.

2.1 Introduction

IS in the CE may be seen as a business model innovation (Baldassarre et al., 2019) based on technical innovations by; a) exchanging waste, resources, and energy (Fraccascia et al., 2019), b) collaborating with stakeholders to implement it, and c) operating a local CE system (Short et al., 2014), and a sustainable business model innovation to gain value from turning waste into valuable resources (Short et al., 2014; Timmermans & Witjes, 2016).

Cooperation between stakeholders is claimed to be crucial for allowing the transformation from the linear model to a circular model through IS (Xiang & Yuan, 2019). Some authors have argued that it is essential to encourage different stakeholders to increase the uptake of this new model among companies (Ghinoi et al., 2020). Abreu and Ceglia (Abreu & Ceglia, 2018) argue that implementing the CE through IS initiatives is vital to encourage business and non-business actors to collaborate to ensure complex synergies. As stated before, there have been limited empirical studies on the transition towards circular systems (Domenech & Bahn-Walkowiak, 2019). However, IS offers background on implementing and ensuring a resource-efficient system that helps guide the transition (Abreu & Ceglia, 2018).

CE-based strategies from an IS perspective can be facilitated by the collaboration between stakeholders such as companies, policymakers, and institutions to ensure transition towards a CE (Saavedra et al., 2018). This section also depicts how IS has been promoted through mechanisms that have not been previously explored in the literature and seeks to take advantage of existing technologies to evolve IS implementation. Then, in this same section, it is also shown how IS has been implemented in different parts of the world, depending on their activities and the type of waste exchange used to carry out a symbiosis.

2.2 Industrial symbiosis context

Despite all the efforts made to implement IS initiatives globally (Figure 1) or at least increase its potential, IS is still a niche strategy that faces multiple

challenges (e.g. regulatory, legislative barriers and financial hurdles, organisational issues) (Ormazabal et al., 2018). The solutions to create IS-related circular models have relied on different pathways in China and Europe that account for most case studies of implementing solutions to close the loop on materials (Rincon-Moreno et al., 2020).

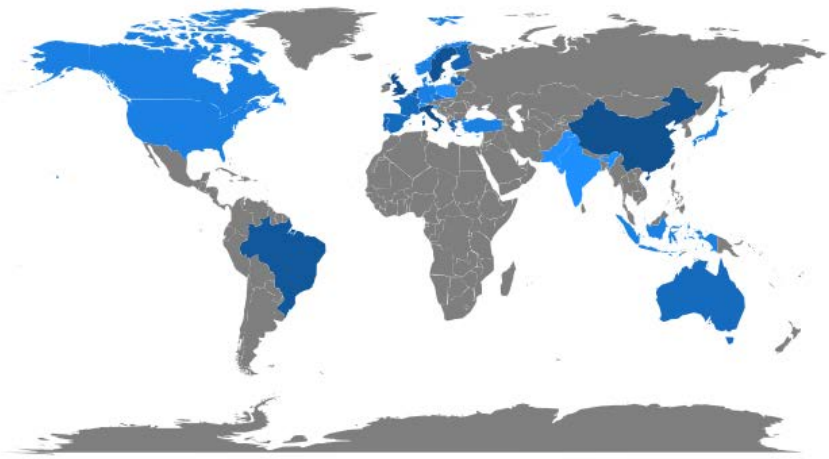


Figure 1. Country scientific production

2.2.1 Industrial symbiosis cases

To observe the different case studies worldwide, Table 2 highlights the cases organised by region, which are arranged based on the number of cases studied. The case studies in Table 2 were also depicted according to their economic activities (Neves, Godina, Azevedo, et al., 2019). Many of the IS initiatives shown in Table 2 pursue efficiency in resource consumption. Although ecological interest might arise as the fundamental reason for developing IS, self-interest is a primary reason organisations collaborate in IS networks (Lombardi & Laybourn, 2012). China is undoubtedly the country with the most case studies of IS reported in the literature and followed by North and North-West Europe in countries such as the United Kingdom, Sweden, Denmark, and the Netherlands (Bassi & Dias, 2019).

Table 2. IS case studies

Country	Location/Region	Activity	Type of Waste-to-Resource Exchange
Australia	Kwinana (Beers et al., 2008; Harris, 2007; MacLachlan, 2013)	Manufacturing, agriculture, energy supply, water, and waste	A significant volume of inorganic process residues, non-process waste, low-grade heat and water conservation reuse.
China	Guitang (Mathews & Tan, 2011; L. Shi & Chertow, 2017; Wang et al., 2018; Y. Zhang et al., 2013)	Manufacturing, water and waste, energy supply and agriculture	Shares several resources and energy flow under shared corporate management.
	Shandong Lubei eco-industrial park (Guo & Hu, 2011; X. Zhang & Chai, 2019; Y. Zhang et al., 2013, 2015)	Manufacturing, agriculture, energy supply, water, and waste	Ammonium phosphate, sulfuric acid, and cement joint-production plants.
	Tianjin (Cerceau et al., 2014; Qi & Wang, 2011; B. Yu et al., 2015; C. Yu et al., 2015; F. Yu et al., 2015a)	Agriculture, energy supply, construction, manufacturing, water, and waste	Wastewater reuse and industrial solid waste exchange.
Denmark	Kalundborg (Branson, 2016; Chopra & Khanna, 2014; Domenech & Davies, 2011; Jacobsen, 2006)	Energy supply, agriculture, and manufacturing	Water exchanges and supplies waste heat as steam, hot water, and cooling water for various applications.
Finland	Kymenlaakso (Mattila et al., 2010; Pakarinen et al., 2010; Sokka et al., 2011)	Manufacturing, energy supply and water and waste	The mill has developed an industrial district, including power plants, several chemical companies, and

Country	Location/Region	Activity	Type of Waste-to-Resource Exchange
			water treatment plants.
Germany	The Spremberg paper mill (T. Vollmeier, 2015)	Manufacturing	The mill is the primary customer of the combined heat and power (CHP) plant. Besides using the mill's wastes, the CHP plant uses a mix of refuse-derived fuels as input.
India	Nanjangud (W. S. Ashton & Bain, 2012; Bain et al., 2009, 2010)	Manufacturing and agriculture	Recovery, reuse, and recycling of residuals such as bagasse, food residues, non-hazardous ash and non-hazardous gas.
Italy	Abruzzo motorcycle district (Simboli et al., 2014; Taddeo et al., 2017)	Manufacturing	The district comprises a large motorcycle producer and a network of 18 SMEs that supply parts and raw materials.
Japan	Kawasaki (Cerceau et al., 2014; H. Dong et al., 2014; Ohnishi et al., 2017; van Berkel et al., 2009)	Manufacturing, port-based industrial complexes and water and waste	Fourteen symbiotic projects, including municipal garbage collection, a wastewater treatment plant and a group of industrial and commercial waste collectors.
Netherlands	Rotterdam Harbour Industrial Ecology	Manufacturing, agriculture, sale	Initiated by industry actors'

Country	Location/Region	Activity	Type of Waste-to-Resource Exchange
	Project (L. Baas, 2011; L. Baas & Boons, 2007; L. W. Baas & Korevaar, 2010; Cerceau et al., 2014).	and repair, residential areas, and port	interest in the socio-economic welfare of new employees.
Portugal	Relvão Eco-Industrial Park (REIP)—Chamusca (Costa & Ferrão, 2010)	Water and waste, manufacturing, and agriculture	REIP has created symbiotic exchanges, including a paper pulp producer near the REIP that delivers ashes from its boiler to a fertiliser producer in the REIP and receives agricultural waste from local farms to be used as fuel.
South Korea	Ulsan (Behera et al., 2012; Kim et al., 2018; H.-S. Park & Behera, 2014; J. M. Park, 2015; J. Y. Park & Park, 2014)	Manufacturing, water and waste, energy supply and sale and repair	Seventy symbioses were identified, ranging from collective utility systems (power, water, heat) to by-product exchanges.
Spain	Galicia (Cerceau et al., 2014)	Port-based industrial complexes	Integrated fishing waste management.
Sweden	Landskrona IS programme (Mirata & Emtairah, 2005)	Manufacturing, agriculture, transportation, and storage	Supports exchanges in various sectors, including chemical, waste management, metal processing and recycling.

Country	Location/Region	Activity	Type of Waste-to-Resource Exchange
UK	The industrial district of the Humber Region (Mirata, 2004; Velenturf, 2016b)	Energy supply, manufacturing, and agriculture	This network provides bio-based developments in the energy sector and optimises material and energy flows, including waste.
United States of America	Barceloneta (W. Ashton, 2008; W. S. Ashton, 2009, 2011; Chertow et al., 2008)	Agriculture, manufacturing and water and waste	Most firms participate in utility sharing, joint service provision and by-product exchange.

In some cases, such as Sweden, Germany, Finland, Japan and Italy, the main preconditions that allowed the creation of symbiotic exchanges were that some waste-to-resource exchanges were already implemented in the region, and companies had previous capabilities in collaborative projects. Furthermore, thus, companies had already the required mindset, know-how and skills, and a high level of awareness of environmental issues and legislative pressure (Evans, S., Benedetti, M., & Holgado Granados, 2017).

In regions such as Portugal, Italy, Japan and Korea, other factors played a role in their realisation, namely the local and national governments. Other stakeholders were also supportive during the creation of the IS networks; for instance, they provided funds and promoted conditions that helped further develop the network and collaboration among companies (e.g., creating recycling norms for different types of waste in Korea). In the Netherlands, some IS initiatives have made eco-industrial clusters by pursuing CE principles. IS is a business model focused on generating value from waste (Baldassarre et al., 2019). Kern, Sharp, & Hachmann (2020) suggested a more comprehensive analysis of

the roles of different forms of international organisations and networks, as much of the current work on transitions focuses on national policy or local players.

Freitas & Magrini (2017) also examine IS potential in industrial construction waste to transform waste management into a resource management strategy nurturing IS networks. An endeavour to link the contributions of resource management in an IS as a strategic approach to reaching a CE may be driving waste management firms to evaluate industrial waste as a source for a secondary material market (Domenech et al., 2019; Saavedra et al., 2018). In some other IS cases, such as in China, the main precondition for IS implementation was that the government had the tools to influence companies' decision-making process strongly and the authority to shape the business environment (H. Shi et al., 2010).

China's CE growth is built on sound policies to construct a broad supply chain through regional industrial parks to develop CE (Fraccascia et al., 2019; Mathews et al., 2018). In the European Union, on the other hand, the circularity in production processes is focused on building secondary materials markets to minimise reliance on virgin resources, which has helped expand IS efforts in some countries (Bassi & Dias, 2019; Petit-Boix & Leipold, 2018).

However, only a few nations in Europe are following CE concepts in which IS now plays an important role that may be regarded as effective in tackling the difficulties of the CE, according to the European Union criteria (Mazur-Wierzbicka, 2021). Moreover, IS remains a niche approach with several obstacles (e.g., legal, legislative, and financial impediments, organisational concerns) (Ormazabal et al., 2018) and has been embraced in a limited number of industries (Brown & Bajada, 2018; Cramer, 2020a; de Jesus & Mendonça, 2018). Therefore, the expansion of IS has been discordant in Europe due to enacting policies at the country level (Bassi & Dias, 2019). This discordance allows the proliferation of IS activities in only certain countries such as Italy, Sweden, Germany, Denmark, The Netherlands, Finland, the United Kingdom and Portugal (L. Baas & Boons, 2007; Evans, S., Benedetti, M., & Holgado Granados, 2017). Other European countries, such as Spain, while not having many reported cases of IS in the

literature, have tried to promote programs for the adoption of IS (Ferreira et al., 2019).

2.3 Barriers to implement an IS

This section addresses the most common barriers and drivers when implementing an IS (Neves, Godina, G. Azevedo, et al., 2019). Although several documented cases of IS show the benefits of adopting it, IS collaborations are sometimes challenging to initiate (Velenturf, 2017). These cases of IS created the most cases from the design and the creation of the companies themselves. However, there is not much evidence between companies operating for years in the IS literature.

There are still barriers that can stop companies from entering the IS and drivers that can promote symbiosis implementation. The list of barriers when implementing IS is wide. The first set of barriers is related to the lack of collaboration between local companies, as shown in Table 3. Companies do not feel comfortable sharing information with other companies; therefore, a partnership is a complex task (Velenturf, 2016a).

Table 3. Most relevant barriers to enabling IS

Barriers	References
Lack of trust among locals in new partnerships. Lack of willingness to collaborate. Lack of intercompany cooperation.	(Bacudio et al., 2016; Ceglia et al., 2017; Golev et al., 2015; Gordon et al., 2012; Jensen et al., 2012; Patricio et al., 2018; Walls & Paquin, 2015)
Lack of information sharing among locators	(Bacudio et al., 2016; Domenech et al., 2019; L. Dong et al., 2016)
Lack of Top Management support	(Bacudio et al., 2016; Ormazabal et al., 2018; Zhu et al., 2014)
Lack of institutional support. Deficient institutional framework. Lack of policy to incentivise IS	(Bacudio et al., 2016; Kirchherr et al., 2018; Liu et al., 2015)
Legislation and regulation, policy. Too restrictive regulation. Fragmented regulation systems	(Behera et al., 2012; L. Dong et al., 2016; Geng & Doberstein, 2008; Golev et al., 2015; Mathews & Tan, 2011; Pajunen et al., 2013; Papathanasoglou et al., 2016; Walls & Paquin, 2015)

Barriers	References
Lack of technology and infrastructure readiness	(Abreu & Ceglia, 2018; Bacudio et al., 2016; L. Dong et al., 2016; Kirchherr et al., 2018; Ormazabal et al., 2018)
Lack of time	(Domenech et al., 2019; Patricio et al., 2018)
Lack of training for implementing IS. Lack of awareness of IS concepts. Lack of knowledge/information. Inadequate information system	(Bacudio et al., 2016; de Jesus & Mendonça, 2018; L. Dong et al., 2016; Geng & Doberstein, 2008; Golev et al., 2015; Mauthoor, 2017; Ormazabal et al., 2018; Papathanasoglou et al., 2016; Patricio et al., 2018; Watkins et al., 2013)
Lack of consumer awareness and interest. The rigidity of consumer behaviour.	(de Jesus & Mendonça, 2018; Ormazabal et al., 2018)
Lack of funding to promote IS. Lack of economic incentives for companies to purchase "second-hand" materials. Lack of market incentives to reuse waste.	(Bacudio et al., 2016; Geng & Doberstein, 2008; Papathanasoglou et al., 2016; Winans et al., 2017)
Risk and uncertainty are linked to difficulty identifying costs-benefits and return on investment.	(Domenech et al., 2019; Golev et al., 2015; Pajunen et al., 2013; Walls & Paquin, 2015)
High investment and transaction costs. Significant up-front capital investments.	(Domenech et al., 2019; Kirchherr et al., 2018; Mathews & Tan, 2011; Pajunen et al., 2013; Teh et al., 2014)

On the other hand, there is a lack of commitment from the company's management and a lack of institutional support that encourages IS implementation. In many cases, the law is very restrictive and makes collaboration between companies difficult since, for example, a company's waste cannot be sold directly to another company. In addition, people and infrastructure are not currently prepared to face this change since people need training. In some cases, implementing IS measures requires a shift in technology or infrastructure and time.

Many companies have not detected awareness for their clients since they are, on many occasions, reluctant to change. Finally, a significant barrier that becomes known in different ways is the economic issue. Companies demand financial incentives and yet do not find them. Identifying the benefits, they will

obtain against the costs is challenging since they consider that development investments are very high.

2.3.1 Drivers to facilitate IS implementation.

Many of the barriers listed in the previous section are drivers in many companies. In this case, the economic aspect is seen as an essential driver. Companies find drivers in the IS to reduce their costs. They also consider that the existing financial aid pushes companies to implement it. When agencies or institutions give assistance or incentives, companies are motivated and get more involved, and when they do not receive that help, their interest declines.

Table 4 highlights the most relevant drivers mentioned in the literature on IS. A factor previously identified as a barrier: collaboration and trust between different agents is seen as an opportunity to share information and improve processes and costs thanks to the joint work with other companies. In this sense, it looks enriching to have facilitators to accompany and help in this creation of collaboration. These facilitators can be public agents, associations, universities, or research centres.

Table 4. Most relevant drivers to enable IS

Drivers	References
Create new areas of revenue. Increase turnover for the company. Decrease company costs with resources.	(Domenech et al., 2019; Ormazabal et al., 2018; Pakarinen et al., 2010; Patricio et al., 2018; Walls & Paquin, 2015; F. Yu et al., 2015b; Zhe et al., 2016)
Funding, financial support, financial incentives	(de Jesus & Mendonça, 2018; Mortensen & Kørnøv, 2019; Teh et al., 2014; Valentine, 2016; F. Yu et al., 2015b)
Legislation and government regulation. Increasing environmental legislation and environmental standards	(de Jesus & Mendonça, 2018; Mortensen & Kørnøv, 2019; Pajunen et al., 2013; Pakarinen et al., 2010; Teh et al., 2014; Walls & Paquin, 2015; F. Yu et al., 2015b)
Build new partnerships with other companies. Trust and cooperation among diverse partners. Collaboration.	(de Oliveira et al., 2018; Domenech et al., 2019; Mulrow et al., 2017; Teh et al., 2014; Valentine, 2016; Walls & Paquin, 2015)

Drivers	References
Effective information management. Information sharing. Access to knowledge.	(Liu et al., 2015; Mulrow et al., 2017; Teh et al., 2014; Valentine, 2016; Zhe et al., 2016)
Third, bodies such as governments, industry associations and research and education institutions as facilitators or coordinators.	(Abreu & Ceglia, 2018; de Oliveira et al., 2018; Mortensen & Kørnøv, 2019; Walls & Paquin, 2015)
Achievement of the company's environmental policy and targets. Change to a more sustainable business model. Corporate social responsibility. Corporate culture.	(Domenech et al., 2019; Ormazabal et al., 2018; Pajunen et al., 2013; Valentine, 2016; F. Yu et al., 2015b)
Access to innovation. Replacement of out-of-date technology with a more relevant one	(Domenech et al., 2019; Teh et al., 2014)
Acquiring new clients	(Domenech et al., 2019)
Marketing reasons	(Patricio et al., 2018; Teh et al., 2014)
Social awareness. Stakeholder pressure and public pressure	(de Jesus & Mendonça, 2018; Mortensen & Kørnøv, 2019; Teh et al., 2014; Walls & Paquin, 2015; F. Yu et al., 2015b)
Geographical proximity. Small geographical scale	(Mortensen & Kørnøv, 2019; Mulrow et al., 2017; Teh et al., 2014; Walls & Paquin, 2015)
Awareness of the waste and by-product flows that are available for utilisation.	(Pakarinen et al., 2010)
Reduced dependency on developed countries for the importation of raw materials	(Chertow, 2007)

Companies also believe that IS can help them achieve a more sustainable business model that meets the company's environmental policy objectives. In addition, the IS will allow them to innovate, thus obtaining new customers. Industrial symbiosis can help companies realise that they can take advantage of waste or by-products from other companies, thereby reducing dependence on raw materials.

Although the barriers commented that customers were not aware and did not demand changes to companies, it is observed that there is a social awareness that pressures and requires a shift from the companies. In this way, it can be

affirmed that we are facing a change where although there are still clients who do not see the shift towards a CE necessary, intense social pressure is changing the course of companies. As observed in this study, many of the barriers that have been identified coincide with the drivers. Therefore, all the agents involved must do their part: public administrations, clients, associations, and companies. The different agents must go to one and bet on sustainability.

Facilitators such as public agents, universities, associations, or research centres can drive IS actions and fruitful collaborations. In addition, these facilitators may be responsible for many of the identified factors being seen as drivers and not as barriers, emphasising the benefits collaboration between industries can bring. So, facilitators must create a framework of cooperation where companies feel comfortable exchanging information and where a climate of trust can be made.

2.4 Addressing IS transitions

The previous sections show that IS has been implemented in different world regions. Nonetheless, its implementation has not been disseminated more widely to allow for an acceleration towards a CE model. The fundamental problems identified are a lack of trust, ambiguity about the advantages, a lack of awareness of the notion of IS, and a lack of information exchange.

However, other elements are frequently alluded to as drivers for the formation and growth of IS networks, such as the desire to minimise raw material and waste disposal costs and the potential generating of money. In addition to these factors, current rules and legislation have impacted IS practices. In that manner, the concept of IS has evolved. As a fundamental pillar of the CE, studies on the subject linking the two concepts have become more evident (Abreu & Ceglia, 2018).

Proof of this has been the evolution of the idea between 2015-2022. As shown in Figure 2, when the keywords "circular economy", "industrial symbios*", and "transition" are analysed in papers, reviews, proceedings and book chapters, growth in the study of IS in recent years can be seen. However, as shown in

Figure 2, transition and CE are one of the topics that have been the least studied in the literature according to the keywords network, which has IS as the central node of research.

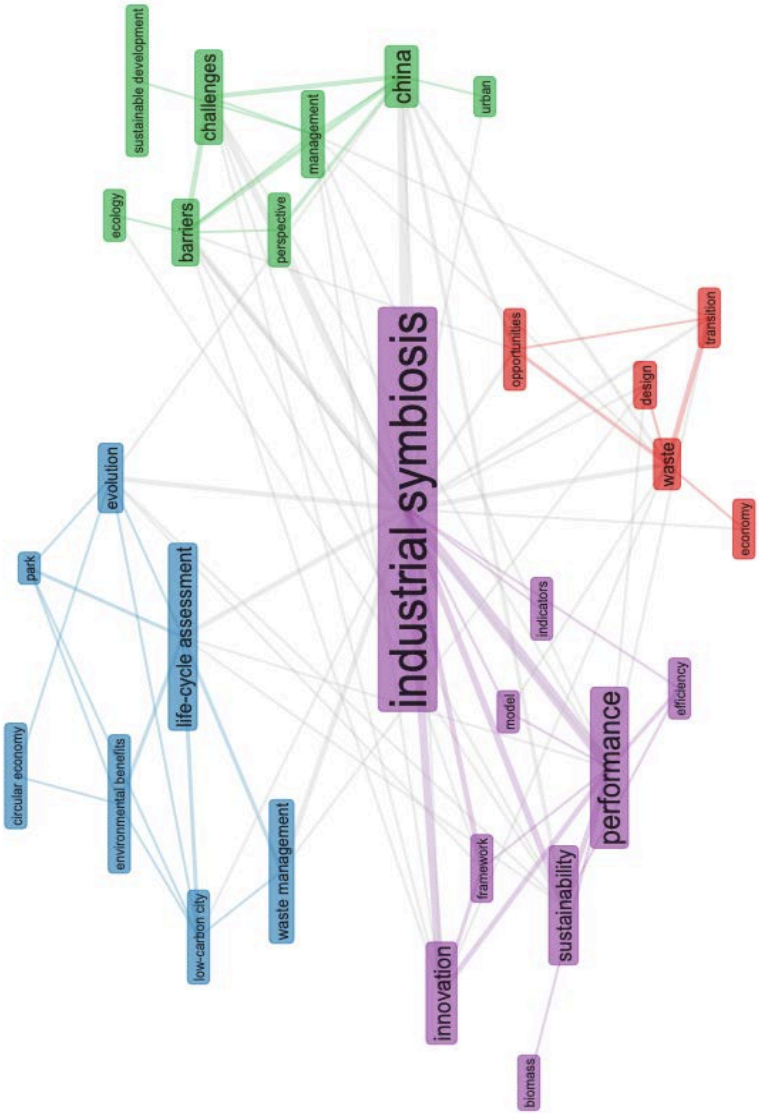


Figure 2. Semantic network of the IS topic within a CE

Although it does not seem clear why the transition of IS within a CE has not been widely studied in the literature, it can be inferred that this has been because the conceptualisation stage of the CE is still a topic of discussion in the literature. This low volume in the literature has made it challenging to search for studies about the transition process in academia (Ghisellini et al., 2016; Kirchherr et al., 2017; Prieto-Sandoval, Jaca, et al., 2018). However, a more detailed study of the literature shows studies using frameworks, guidelines, and methods. Table 5 shows the literature on implementing a CE based on IS processes and how it deals with implementation issues focused on six research topics.

Table 5. Literature addressing the implementation of IS within a CE

Research focus	Form of implementation
Industrial symbiosis	Guidelines (Smol et al., 2021), framework (Cervo et al., 2020; Pyakurel & Wright, 2021; Yuan et al., 2019), policies recommendations (Bian et al., 2020; Branca et al., 2021; Xue et al., 2019; C. Yu et al., 2015), conceptual models (Mortensen & Kørnøv, 2019) and industrial strategies (Abreu & Ceglia, 2018).
Waste	Recommendations (Mohammadi et al., 2021).
Circular economy	Frameworks (Ghisellini & Ulgiati, 2020; Iacovidou et al., 2021; Kerdlap et al., 2019; Khan & Ali, 2022; Walmsley et al., 2019), roadmaps (Vanhamäki et al., 2020), strategies (Kalmykova et al., 2018; Pan et al., 2015) and models (Chari et al., 2022).
Design	Recommendations (Kanda et al., 2021; Silva et al., 2019), toolbox (Belaud et al., 2019) and frameworks (V. de Souza et al., 2019).
Management	Management systems (Barón Dorado et al., n.d.)
Innovation	Frameworks (Chen, 2020; Feiferytė-Skirienė & Stasiškienė, 2021), database (Genc, 2021) and models (Fisher et al., 2020),

Most studies generally refer to guidelines or frameworks for identifying synergy opportunities (Pyakurel & Wright, 2021; Smol et al., 2020). Also, recommendations on policy issues or industrial strategies improve the potential of incorporating IS in city planning (Bian et al., 2020; Music, 2019; C. Yu et al., 2015; Yuan et al., 2019). Some studies recommend methods of cooperation through digital technologies (Branca et al., 2021; Marconi et al., 2018) that enhance collaboration between agents to develop symbiosis.

Moreover, when symbiosis comes to be considered within a broad CE concept, analytical frameworks are more frequent in the literature. Studies that focus on developing better information-gathering capabilities (Iacovidou et al., 2021) work on barriers and enablers (Khan & Ali, 2022) or help to identify technologies (Kerdlap et al., 2019) stand out. In this sense, studies are also beginning to show that strategies that consider the entire value chain (Kalmykova et al., 2018) and therefore include a larger group of stakeholders (Masi et al., 2017) are beginning to be implemented. Several studies conclude that redesigning supply chain networks is necessary (V. de Souza et al., 2019) and new recommendations on managing stakeholder relationships (Silva et al., 2019). Also, databases are proposed to help in decision-making and opportunity capture (Fisher et al., 2020; Genc, 2021) or frameworks to deliver strategies to support and improve relationships for these stakeholders (Chen, 2020; Feiferytė-Skirienė & Stasiškienė, 2021).

Few studies have stood out for focusing on a broader vision to ensure the success of synergies in specific symbiosis projects or activities. There is a lack of an integrated and systematic approach to creating synergies. The study by Cervo et al. (2020) offers a methodological framework to provide practitioners with a clear route to developing symbiotic relationships in their region. Vanhamäki et al. (2020) expose a roadmap process as a strategic instrument for implementing symbiotic synergies at a regional level. Likewise, Kanda et al. (2021) offer recommendations using the IS and business ecosystems literature to implement CE systems from an ecosystem perspective.

When dealing with business models for symbiosis where previously isolated value chains may be intertwined, the literature shows a need for a systemic

perspective. So, to foster IS and contribute to creating a fair playing field across industries, IS will demand some level of shared strategic visions and collaborative decision-making that nowadays are missing (Herczeg et al., 2018; Vanhamäki et al., 2020). Especially IS within a CE where enterprises are integrated into a sophisticated network of IS linkages involving a wide range of stakeholders (i.e., government, social actors, facilitators, and firms). This collaboration necessitates an emphasis on how transitions occur to understand better how it operates in reality (Flynn et al., 2019).

2.4.1 Sustainability transitions to implement IS

Transitions are defined as "processes of structural change in social sub-systems" that occur when dominant structures are put under strain, either by external changes or through an endogenous innovation process, to offer direction for the wicked challenges we are presently confronted with (Peterson et al., 2022).

In this context, the transition is a process where waste becomes a resource in the current scenario. Related practices require better managerial attention to effectively resolve environmental, economic, and societal issues to improve business performance. Moreover, using IS as one of the fundamental methods for managing resources and waste would necessitate collaboration among stakeholders to develop a CE system (Domenech et al., 2019; Saavedra et al., 2018).

So, to implement IS, changes must occur at a level where systemic changes may sprout, also known as the meso-level (Barreiro-Gen & Lozano, 2020). In an IS, many industrial sectors converge to exchange materials and energy. At this level, where one enterprise's waste (materials or energy) becomes another company's raw material, sectors such as energy supply, water supply, and transportation can be considered socio-technical systems. These systems are made up of (networks of) actors (individuals, corporations, and other organisations, collective actors) and institutions (societal and technical norms, legislation, and good practice standards), as well as material objects and information.

A transition at the meso-level entails significant changes on several points: technical, material, organisational and institutional (Markard et al., 2012). A characteristic of sustainable transitions is that advice and governance often play an essential role. Political actors, policy and institutional support, can play a crucial role in a guided transition (Barreiro-Gen & Lozano, 2020). One of the reasons sustainability transition types of research have aroused such interest and ingenuity is because it explores "big picture" issues.

In terms of theory, four frameworks have received much attention in transition studies thus far. Transition management, strategic niche management, the multi-level perspective on socio-technical transitions, and technological innovation systems take a systematic approach to the vast change processes of socio-technical systems (Markard et al., 2012). Table 6 summarises the main characteristics of the different reference frameworks used in transition studies.

Table 6. Frameworks in transition studies.

Sustainability transition frameworks	**Main features**
Multi-level perspective	It contends that transitions occur as a result of dynamic processes occurring within and between three analytical levels (Geels & Schot, 2010): 1) niches, which are protected spaces and the locus for radical innovations; 2) socio-technical regimes, which represent the institutional structuring of existing systems, leading to path dependence and incremental change; and 3) exogenous socio-technical landscape developments.
Technological innovation systems	Regarding the stability/change tension, the TIS method emphasises creating innovative innovations rather than the stability of current systems (Markard et al., 2012).
Strategic niche management	Radical innovations develop in 'protected areas (e.g., financed demonstration projects, experiments, or devoted users such as the Army), sheltered from mainstream market selection (Köhler et al., 2019).
Transition management	It implies that policymakers may shape transitions in four phases (Loorbach et al., 2017): 1) Strategic actions in a 'transition arena' strive to establish visions and identify viable transition routes. 2) Tactical efforts include developing more precise plans for tangible pathways, developing agendas, and supporting coalitions for these routes. 3) On-the-ground activities such as innovation experiments, demonstration projects, and implementation

Sustainability transition frameworks	Main features
	activities are examples of operational activities. 4) Reflexive exercises should result in vision changes and articulating optimal practices.

Much of the work on transition research begins with recognising that transitions cannot be regulated purely from the top down and that various players are involved. Transition Management and Strategic Niche Management both suggest governance methods centred on transitions. The central notion of Transition Management's transition arenas, for example, is to enable changes by bringing together players from research, politics, civil society, and industry and developing cooperative rather than competing ties. It should be noted that the impediments to such collaboration might be deeply ingrained due to the entrenched character of existing socio-technical systems, as much of the previous thought on transition governance focuses on the early stages of the process (Köhler et al., 2019).

Because research on the role of enterprises and sectors in sustainability transitions is still in its early stages, there are several potentials for additional work on the themes mentioned above and new ones. One argument for future study is that transitions to the next stage of development occur in regions and industries. Transition studies are broadening their attention from single systems (energy, mobility, water, food, and health) to 'multi-sector' transitions and the interplay of diverse systems (Markard, 2018).

2.4.2 Transition management framework

The CE is regarded as a single socio-technical structure that transforms industrial practices. IS is a pillar to be the dominant industrial system implemented by different countries (Schot & Kanger, 2018). Some initiatives, such as IS, have been used in the Netherlands to create eco-industrial clusters by pursuing CE principles. IS is a business model focused on generating value from waste (Baldassarre et al., 2019). As industries are reasonably accountable for

depleting resources, they play a pivotal role in societal transitions between the business environment and the wider environment to achieve a sustainable production model (Bidmon & Knab, 2018). The engagement and influence required by multiple stakeholders to change production models are essential as firms, on the other hand, cannot become economically, environmentally, or socially competitive; they can only lead to more sustainable production practices within society (Tukker et al., 2008).

This societal perspective view of business as a driving force to tackle social and environmental issues has been called for exploration by Loorbach & Wijsman (2013). Loorbach, Frantzeskaki, & Avelino (2017) suggest transition management (TM) research as a proxy for a deliberative process to accelerate organisational and operational change through a shared strategic vision among stakeholders. So, the TM process may set up strategies to guide a coalition of stakeholders to create new value for businesses and other stakeholders (Loorbach & Wijsman, 2013).

The TM pursues an understanding of how multiple agents may engage and act to influence the desired changes by involving frontrunners, outsiders, and other agents with a stake in such transition (Loorbach et al., 2017). This way, research that sets up the strategies to fundamentally guide the coalition of advocates to create new value for businesses and society through the TM process is vital (Loorbach & Wijsman, 2013).

The principles that guide the transition process have been translated into a management framework. The elements of the TM framework distinguish four levels: arena, agenda, experiments, and monitoring (Figure 3). These components or transition fields can help solve societal processes, persistent problems, fundamental change, and innovation processes, such as the challenge of creating circular systems. Likewise, the TM framework provides tools that develop transition-based governance strategies, including a broader range of governance instruments (Loorbach et al., 2017).

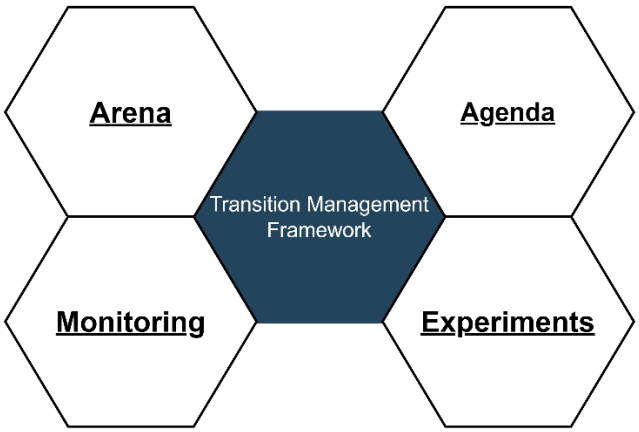


Figure 3. Transition management framework (Adapted from Loorbach et al., 2017)

The framework's structure is meant to be followed sequentially. This sequence implies that transition arenas are followed by agenda and experiment instruments, and the cycle concludes with monitoring. The four levels of the framework are listed below (Loorbach & Wijsman, 2013):

Transition Arena: a stage the future is jointly deliberated and envisioned.

Transition agenda: activities aimed at the medium and long term, focusing on changes in existing organisations, institutions, rules, and physical or financial infrastructures.

Transition experiments: short-term actions that focus on experiments and actions that practice, test, and exhibit alternative ideas, practices, and social interactions.

Transition monitoring: learning process about the system's current state and dynamics and probable future conditions

TM is an ongoing process of searching, learning, and experimenting within societies. TM offers an incentive for action and intangible benefits in collaborative governance and system thinking. It promises to provide room for alternative ideas, practices, and social interactions (Loorbach et al., 2016; Wittmayer & Loorbach, 2016).

TM's fundamental aspect is facilitating transitions by gathering actors from academia, government, civil society, and industries to develop a cooperative instead of a competitive relationship (Köhler et al., 2019). Moreover, studies on transitions claim further research to create more observations on achieving adoption (Table 7). In this sense, the transition activities help develop specific plans for specific routes and build support agendas and coalitions for these routes (Köhler et al., 2019).

As shown in table 7, TM studies have been applied in different types of research. Studies on marine governance, cities, energy transitions and sustainable mobility have been studied. Although there has been an increase in TM research, very few TM studies focus on issues related to CE and IS. Though Cramer, 2020a and Peterson et al., 2022 use the TM framework for implementing CE, none of them illustrates how the transition should be made and what steps should be followed.

Table 7. Uses of TM in the literature

Authors	Focus
Veldhuizen, Caroline	Reveals the complexity of policy transfer in diverse institutional and socio-political contexts and identifies some key factors which influence TM
Chen, Huifa Shan, Yuan George Tang, Qingliang Zhang, Junru	Reveals that TM facilitates an upward adoption of carbon management trends annually during the study period
Harlow, John Johnston, Erik Hekler, Eric Yeh, Zoë	Combine TM, and the multiple streams approach to increase the transformative potential of transition arenas.
Hopkins, Debbie Schwanen, Tim	Applies the TM framework to ongoing automated vehicle transition dynamics in the UK.
Maryam Nastar, Shabana Abbas, Carlos Aponte Rivero, Shona Jenkins & Michelle Kooy	Investigates how TM can be implemented effectively to improve access to water for disadvantaged groups

Authors	Focus
Kelly, Christina Ellis, Geraint Flannery, Wesley	Provide both a more realistic conceptualisation of change and the capacity to guide operationalisation through TM in marine governance
Hölscher, Katharina Wittmayer, Julia M. Avelino, Flor Giezen, Mendel	Shows opportunities and intricacies of TM as a facilitated empowerment process that seeks to empower 'frontrunners' to define and take up roles in contributing to sustainability transitions in cities
Peterson, Heidi M. Baker, Lawrence A. Aggarwal, Rimjhim M. Boyer, Treavor H. Chan, Neng Iong	Demonstrate how the trajectory of the current linear phosphorous use system could be strategically shifted toward a more circular phosphorous system through TM
Frantzeskaki, Niki Hölscher, Katharina Bach, Matthew Avelino, Flor	Understand the complexity of urban sustainability transitions and diagnose persistent unsustainability problems in cities by applying TM
Cramer, Jacqueline M.	Shows that the governance of the CE implementation at the regional level can be organised in a more networked form of governance through TM.

Loorbach, Frantzeskaki, & Avelino (2017) suggest (TM) research as a proxy for a deliberative process to accelerate change through a shared strategic vision. Cramer (2020a) has dealt with this issue by focusing on CE implementation built upon TM theory and methods that may indicate change orientation. The author advocates implementing CE initiatives as a continuous transformational change to influence initiatives that speed up changes and can be scaled up towards a full CE in a local context. As a result, TM allows exploring and testing alternative social connections, such as those between local governments and people or between citizens and companies. Thus, TM contributes to strengthening alternative dynamics and the empowerment of players to strive to transform current unsustainable systems.

Likewise, some studies suggested understanding collaborative value creation networks within market-based ecosystems that initiate circular business model innovation and associated stakeholder groups (Hofmann & Jaeger-Erben, 2020) under an organisational TM approach. Cramer (2020b) studies the implementation of the CE in Amsterdam using a practice-based model and how it evolves following TM theory.

The author concludes that moving to a CE can be interpreted as a continual accumulation of multiple circular measures running at different rates, accelerated by the absence of fundamental barriers in collaboration with industry and other valuable stakeholders. Additionally, Cramer (2020a) indicates that not yet a structural shift in the direction of CE has been taken as this profound transformation takes time and cannot be completed immediately. However, the author claims that more research in social-political environments would make a more thorough comparison of the implementation mechanisms of a circular system. Various perspectives covering all stakeholders involved in ensuring a transition towards a CE remain a subject of study (Abreu & Ceglia, 2018; Millar et al., 2019).

2.5 Research contribution: Transition management framework to develop a circular economy system based on IS

As observed in previous sections, there is a need to further research a societal viewpoint of business as a driving factor in addressing social and environmental challenges. This insight has fuelled research into new kinds of governance, generically labelled as TM or transition governance (Loorbach & Wijsman, 2013). The word "management" is derived from an overtly normative sustainability orientation: specifying where we want to be, what should be done, and how it should be done (Peterson et al., 2022).

Regardless of existing technical suitability and potential financial and environmental gains obtained in implementing IS (Doménech & Davies, 2011), scaling it up would require extensive collaboration with the industry and other

stakeholders (Velenturf, 2017). So, moving away from a linear model goes beyond turning waste into valuable materials, including a deep knowledge and understanding of relevant stakeholders (Hein et al., 2017). This extensive collaboration creates obstacles to massive IS adoption, so it is vital to define what strategy would bring together diverse stakeholders to implement this solution.

Changes must be fundamentally restructured via transitions. Since industries are somewhat liable for depleting resources, they are critical in playing a significant role in social transitions between the corporate environment and the larger environment to create a sustainable production model within a society (Bidmon & Knab, 2018). So, the CE can be considered a unified socio-technical system involving the change of industrial processes, with IS serving as a pillar to become the dominant industrial system used by many countries (Schot & Kanger, 2018).

Therefore, this study aims to integrate and use concepts and learnings from the emerging area of TM to systematically investigate how to shift from the linear system to a more sustainable mode of production. To that end, it is necessary to apply concepts from the TM literature to regions to develop a conceptual framework for TM. A TM would probably allow IS systems to describe the main features that will enable the region to progress towards this system, whether there are some stakeholders essential to this process to explore future transitions, and to analyse what activities are still relevant to transition towards a CE.

The main contribution to the literature of this thesis would be to create a methodological framework that guides the processes of experimentation and collaboration, how and which stakeholders to mobilise, and what action strategies to recommend implementing. These insights could then be applied to other global regions, such as developing countries, to avoid becoming entrenched in unsustainable management as they expand industrial outputs.

3 Research Methodology

This section presents the research methodology applied in this thesis. It comprises three main phases: (1) conceptualisation, development of the TM framework, and (3) verification of the TM framework. The conceptualisation phase included a literature review in determining the research gap and questions and analysing existing frameworks for facilitating a transition. Moreover, the system boundary is also mentioned in this sub-section. During the development phase, semi-structured interviews and focus groups were used to complement the theory found in the literature with the knowledge gathered from stakeholders in the field of IS and conclude with the TM methodological framework. Finally, in the verification phase, the completeness and relevance of the TM framework were evaluated. The case study method in the Humber region was used to verify the framework.

3.1 Introduction

The research approach should be appropriate for the study topic, objectives, and expected findings. This research focuses on the concept of sustainability transition studies. The aim is to define a framework to develop a TM framework for IS systems to build CE systems. Different research methods were applied to conceptualise, design, and verify the framework.

This research methodology consists of three main phases; first, the conceptualisation phase; second, the development phase and third, the verification phase (see Figure 4). Various research methodologies were used to get the intended outcomes in each step. A comprehensive literature study and determination of the system boundary was undertaken during the conceptualisation phase to identify the research gap, collect the data to answer the research questions, and deliver an initial version of the framework. In the development phase, semi-structured interviews, focus groups, and surveys were used to provide a preliminary understanding of the framework process by combining the theory found in the literature with the empirical observations. Finally, in the verification phase, the case study method was used to finalise the framework's development and evaluate it in another regional context. The case study was conducted in the Humber region, UK.

Figure 4 illustrates the overall research design used in this research. The methods utilised are classified according to the three stages of the thesis: conceptualisation, development, and verification. The background of the study and main discoveries that compose the framework, such as the framework components and development process, is presented. Overall, Figure 4 describes how each approach contributed to the findings. This chapter will go over the three completed phases, and the research methods will be explained in greater detail.

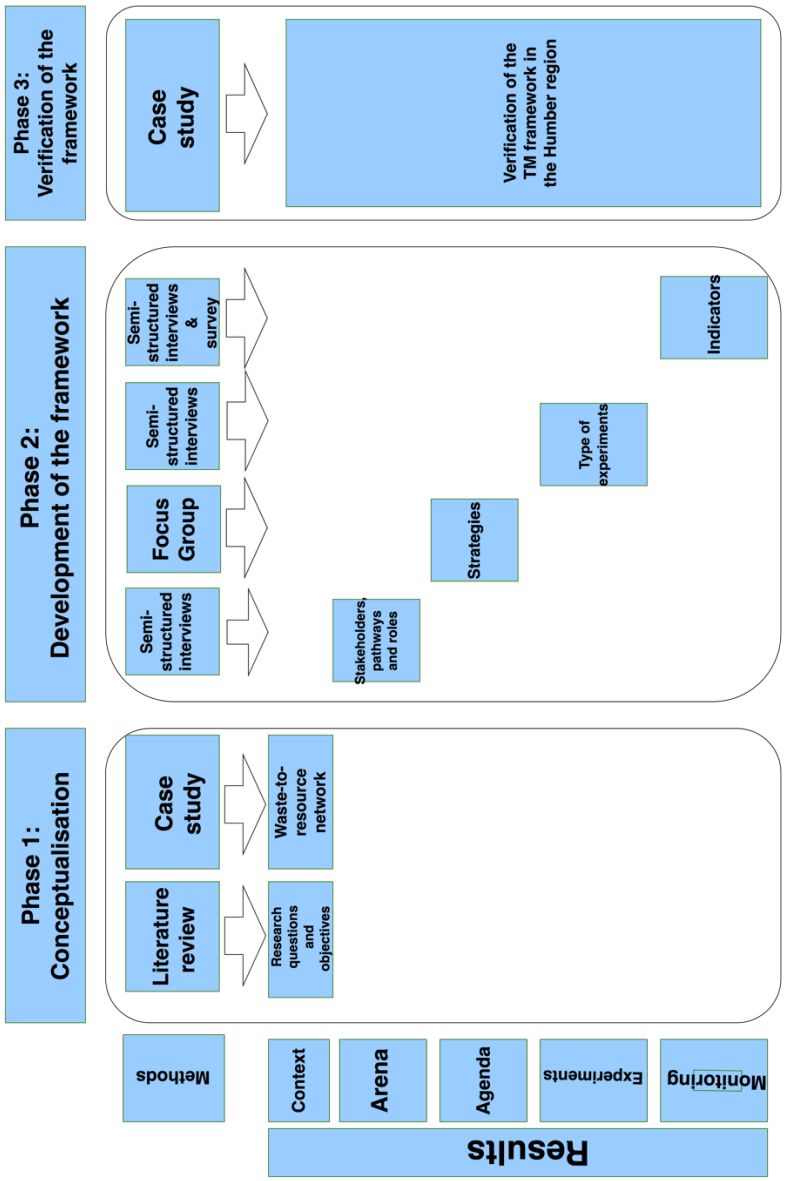


Figure 4. Research design

3.2 PHASE 1: conceptualisation of the framework

During the conceptualisation phase, the literature review was selected as the research approach to analyse existing literature, identify research gaps, and define research questions and objectives. The literature review was chosen because it adheres to methodological rigour while simultaneously highlighting research gaps (Briner & Denyer, 2012; Carvalho et al., 2013; Seuring & Müller, 2008).

The development of the framework was limited to the theory found in the literature in which governance for a transition is still faced with severe implementation gaps (Flynn et al., 2019; Fraccascia et al., 2019; Kern et al., 2020). It is necessary to understand how waste might stand a better probability of becoming a resource for another company (policy, technical, and organisational) that could enable the transition towards an IS system. So, we must know how waste is handled for IS systems' emergence.

So, it is relevant to determine and define the system boundaries. System boundaries relate to the delimitation of the problem of study in IS involving the patterns of resource distribution interwoven with waste management in specific locations (Schröder, 2018). Defining system boundaries is one of the challenges in the governance and management of inter-sectoral and inter-organisational material and energy flows (Korhonen et al., 2018).

Because a TM framework as a governance approach to sustainability transitions (Wittmayer & Loorbach, 2016) should include stakeholders in the system, actively defining the system's boundaries under investigation is a crucial step in building the framework around the IS network with its stakeholders (Walton, 2016). Thus, this thesis selects methods to collect data, generally of a qualitative nature, to establish the research's boundaries.

3.2.1 Literature review

The research gap was identified during the conceptualisation phase, and consequently, the research questions and objectives were defined. The

governance model was defined by specifying a first theoretical version of the four-cycle process.

First, we chose a set of keywords and conducted different searches. The three main keywords used were "circular economy" AND "industrial symbios*" AND "transition*". The search in this study was confined to peer-reviewed journal articles, review articles, conference papers, and book chapters (all published in English), as this is the primary mechanism for quality control in most scientific disciplines when undertaking unbiased knowledge synthesis (Bornmann, 2011).

The keywords associated with the research area were first listed. They then entered an advanced query search in the Science Citations Index (SCI) and the Social Science Citations Index (SSCI) databases. Both are part of the Web of Science Core Collection database (WOS) and are the most commonly used and reliable sources for bibliometric analysis (Kamalski & Kirby, 2012). Although the IS concept has been studied for over 20 years (Chertow, 2000; Kulczycka, J., Uberman, R., Dziobek, 2020), over the last five years, IS research has turned into a sub-field of the CE.

All the abstracts were read to ensure the papers were about IS and its contribution to implementing a CE. The publications were reviewed extensively, and the critical research deficit was identified. The first objective of the literature review was to identify research studies, frameworks and reports describing how the implementation of IS within CE systems has been applied to find the research gap and explain the objectives and contribution of the research. So, those papers not mentioning how value creation and value capture from waste are being implemented were not considered. Finally, duplicate articles were removed, leaving 72 papers from the initial 94 (Figure 5).

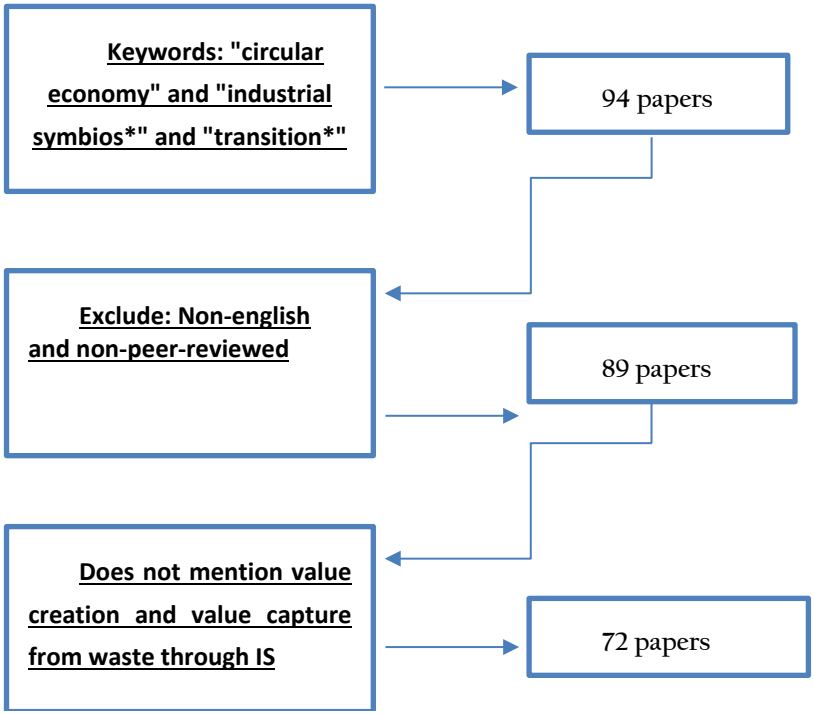


Figure 5 Literature review process

3.2.2 Case study to define system boundary

The boundary of an IS is the geographical scale at which material exchanges and recycling of various forms of waste occur (Chertow & Ehrenfeld, 2012; Ghisellini et al., 2016). Any opportunity to create multiple opportunities across value chains to foster IS networks (Domenech et al., 2019) will likely occur due to industrial activities and geographical proximity among companies in this area (Chertow & Ehrenfeld, 2012; Ghisellini et al., 2016).

For this reason, and according to the literature (Aid et al., 2017; Baldassarre et al., 2019; Genc et al., 2019), three areas were analysed through a case study within the region of the Basque Country to determine what sectors should be included in the system boundaries for this thesis: industrial park, industrial clusters and industrial waste management.

The region of the Basque Country in Spain was used to carry out the analysis to determine the system boundaries. The region was selected because several

studies have been undertaken focusing on achieving circularity (Ormazabal et al., 2016, 2018) and its potential for transforming linear systems into circular systems through IS (Rincon-Moreno et al., 2020). Likewise, some companies have shown advances towards a more circular model (Rincón-Moreno et al., 2021) compared to regions where non-existing IS initiatives have been set in place (Aguilar-Hernandez et al., 2019; Circle Economy, 2018; Prendeville et al., 2018; Vanhamäki et al., 2020).

The case study method was selected as a research strategy to gain significant insight into one process, such as the system boundary restrained in time and space. It is characterised by focusing on depth rather than breadth in a relatively small number of research units or cases following a strategic sample to extract information from these cases (i.e. industrial parks, industrial clusters and industrial waste) (Piet & Hans, 2010).

Firstly, an industrial park is analysed as an essential conduit for determining system boundaries as the potential use of waste as a resource. The selection of an industrial park is due to the high intensity of environmental pressure caused by a high density of industrial activities (Fan et al., 2017). An industrial park may enhance the effectiveness of material and energy flows to advance companies' economic and environmental development (Wang et al., 2016). The industrial park also provides possibilities for reverse logistics, material tracking, improved logistical setups, and collaboration and knowledge sharing (F. F. de Souza et al., 2020).

The companies analysed within one industrial park comprises 306 companies from different sectors with an average of 3 to 5 employees and 300 m2 of usable space, with a small number of companies (13) having more than ten employees. The companies are characterised by their heterogeneity, but due to the number of businesses located near each other, they may take advantage of resource sharing through industry associations (Ormazabal et al., 2018). Companies within the industrial park were asked to provide information about the industrial activity and specific questions about their production processes, such as type and input/output quantity of materials/residue. This information was used to simulate theoretical networks of waste-to-resource exchanges and

to verify that there are real possibilities for IS collaboration within the industrial park.

Using software to simulate the recirculation of materials has been discussed in other studies, where tools to match the supply and demand of wastes have strengthened relationships among companies over time (Albino et al., 2016; Yazan et al., 2016). Similar studies have adopted a related strategy that includes models of an online sharing platform that facilitates waste-to-resources matching (Fraccascia & Yazan, 2018; J. M. Park, 2015).

These simulations were done via a software platform for implementing synergies in IS networks to optimise waste and resource management. The software offers strategic data on local IS potential through the development of open data and machine learning-based material flow detecting technologies. The software delivers a geographical audit on waste flows by running a cartographic analysis of a defined area (i.e. industrial park). The software performs its task following the European nomenclature adapted to recyclers (resource code), and it registers the sectors of activity defined by the European nomenclature glossary (NACE). The NACE nomenclature glossary corresponds to the statistical classification of economic activities in the European Union. The software uses both the resource code to list each company's different resources and wastes.

Additionally, analytically determining system boundaries must also be modified to account for functional interlinkages (Schröder, 2018). As materials are more likely to be used across many industries in a greater area, Vimal (2019) underlined the significance of expanding the geographic boundaries to consider residual reuse beyond the official boundaries of industrial parks. The extended boundary underpins the operation of clusters in an IS, which is the interaction of different business entities that create a cooperative network to achieve competitive advantage by physically exchanging materials, energy, water, and by-products as well as services and infrastructure (Baldassarre et al., 2019). Industrial clusters in an IS are usually started by governmental and commercial actors collaborating to build a strategic network plan (Boons et al., 2017).

These clusters could serve as debate and information exchange platforms as well as supply chain improvement, adaptation, and integration systems (Bezama

et al., 2019). Industrial clusters show high potential for transforming linear systems to circular systems through IS (Rincon-Moreno et al., 2020) as they host highly industrialised sectors. Eventually, two industrial clusters (textile and recycling) created to promote synergies towards a CE are analysed. The clusters selected for the thesis gathered industries with the scope of promoting the transition aligned with IS initiatives. The main objectives of these clusters are to extend collaborations to other companies in the recycling and textile sector.

Nonetheless, as the consumption of raw materials keeps rising, so does waste generation, and with it, waste valorisation remains insignificant (Circle Economy, 2019; Shahbazi et al., 2016). Some solutions are related to shifting the current waste management system (Cobo et al., 2018), whereby no material is wasted or underused (Ghisellini et al., 2016; Prieto-Sandoval, Jaca, et al., 2018). In other terms, waste management in an IS is essential because it underlines recycling materials and energy into usable resources for different actors (Zhu et al., 2011).

This contribution of IS to a better waste management system seems to be underexplored in practical applications (Aid et al., 2017; Domenech et al., 2019). Consequently, waste management is also analysed to define the system boundary as it can help overcome waste-to-resource obstacles. Currently, some local authorities of the Basque Country region (Spain) aim to improve waste collection rates through a "zero waste to landfill" and to enhance the efficiency of its management within a service area. The responsible for executing this regulation is a waste management organisation that manages all potentially recyclable or recoverable waste to avoid landfilling. For this reason, it is essential to know the information compiled by this waste management organisation that serves approximately 2000 companies in the Basque Country (Spain).

The industrial waste management analysis focused primarily on waste generation in 10 different industrial parks in the Basque Country region (Spain) through data recorded by waste collection waste management organisations. The data for this study were collected from primary sources using a SQL database. Data between 2014 and 2018 were collected (waste types and amounts, generation flows, ways and frequency of collection, and several waste

producers). Finally, quantitative data were analysed through a spreadsheet program to process the data to make them practical (Saunders, Lewis, & Thornhill). Quantitative analysis techniques such as graphs, charts and basic statistics were used to describe and examine relationships of waste collection suitable for recovery. So, all industrial sectors with direct influence on waste management and garments may stimulate the creation of synergies.

3.3 PHASE 2: Development of the framework

The literature review identified the gap and the preliminary version of the framework (Figure 6) that tries to fill the gap. The capacity of governance networks such as TM to incorporate a variety of viewpoints is an effective mechanism for producing answers to complex challenges (Nastar et al., 2018). After defining the research boundaries, the next stage was determining the stakeholders and transition pathways. The framework comprises the four-cycle process that describes the transition process and the features that distinguish the TM process the stakeholders should go through when developing a transition. This framework was further developed in the second phase with the different stakeholders. Semi-structured interviews completed the transition arena phase of the framework. This method is meant to understand the stakeholders to develop a shared vision and identify potential transition pathways needed for a transition.

Figure 6 TM framework (Adapted from Loorbach et al., 2017)

Once the transition arena phase has been explored, the transition agenda phase is studied. Stakeholders devise strategies to implement the goals in the

previous step at this stage. So, the participation of experts was sought through participatory methods. First, a focus group was conducted online with different stakeholder groups identified as key to a transition. Subsequently, nineteen semi-structured interviews were conducted for the transition experiments section to understand the day-to-day actions and how they are linked to transition management. Then, a survey was conducted using online questionnaires to enable the monitoring phase of the transition process. Consequently, a version of the TM framework was obtained.

3.3.1 Semi-structured interviews for the transition arena

To improve the integration of long-term (strategic) visions, mid-term (tactical) goals, and short-term (operational) actions, a transition arena is established (Wittmayer & Loorbach, 2016). The transition arena process' primary activity is the creation of a system transformation perspective (Hyysalo et al., 2019). Likewise, it provides a platform for stakeholders, or "frontrunners," to create a shared direction, specific sustainability transition projects, new coalitions, partnerships, and movements (Hölscher et al., 2019). So, the first element is establishing a transition arena where local stakeholders are grouped along with selected pathways of development which are strengthened further through negotiations, teamwork, and coalition formation (i.e. transition experiments) (Wittmayer & Loorbach, 2016).

How the transition arena is organised, including the presence of (or absence of) stakeholders with a learning infrastructure for carrying out the transition, will determine how successful the entire TM process will be. Stakeholders play a crucial part in this transition, as collaboration is essential to gain a long-term vision of cycling materials. Examples include integrating various stakeholder groups or the density of interactions between them (Dóci et al., 2022).

Hence, this section defines the stakeholders that shall be part of the transition arena and which pathways are used to develop the transition model. Since IS does not only occur within an industrial park but can also occur in networks within a geographical area, the stakeholders interviewed belong to this type of symbiosis as defined by the system boundary. An initial list of significant

stakeholders (Table 8) within the system boundaries was developed. Initially, targeted stakeholders were dynamic in activities that controlled resources, delivered value propositions around eliminating waste and promoted tangible and intangible value exchanges between stakeholders expressed as a value network or whose purpose had a relationship with these issues (Hein et al., 2017).

Table 8. Description of the stakeholders

Stakeholder	Description	Type of organisation and role
1	Leader of the CE strategy of the Basque Country 2030.	Public administration (Head of department)
2	A frontrunner in developing a CE business model based on recovering secondary materials	Private organisation (General manager)
3	Add value to the value chain as a coordinator, manufacturer, and innovator to create partnerships through waste-to-resource exchanges with other organisations.	Foundation (Executive director)
4	Designs and manufactures fixed installations and mobile groups to crush construction and demolition waste and the fragmentation of metal scrap.	Private organisation (Sales Executive)
5	Work closely with public administrations on CE activities such as material recovery, reuse, and recycling.	Research institution (Head researcher)
6	Provides consultancy services to companies interested in finding symbiotic opportunities.	Private organisation (Director)
7	Companies within an industrial park	17 managers of manufacturing companies

The chosen stakeholders have a reputation for implementing IS efforts that support a CE between public and private organisations (Mortensen & Kørnøv, 2019). The relevance of organisational traits and representativeness of distinct organisations was examined throughout the stakeholders' identification and mapping process (Friedman & Miles, 2006). A Snowball Sampling Approach (Scott & Carrington, 2011) was used to identify further stakeholders who should be questioned about these concerns as recommended for this type of research (Piet & Hans, 2010). In total, semi-structured interviews were conducted with 23 stakeholders to gain insights on how to govern an IS (Appendix A).

Semi-structured interviews were chosen as a qualitative research method for this thesis to gather and analyse data concerning the stakeholders around the possibilities of transitioning towards an IS system. This type of interview aims to gain information about the experiences of individuals, thereby revealing 'interviewees' standpoints, intentions, and actions to understand the reality within a particular context (Charmaz & Liska, 2013). This methodology allowed it to collect in-depth information about the real possibilities of developing an IS system with the involvement of different stakeholders.

The aspects covered during the interviews included awareness of a waste-to-resource strategy relevance, key stakeholders, and motivations for generating IS initiatives. The semi-structured interviews also define the group of stakeholders and the transition pathways to facilitate the transition in the region. After 23 interviews, a point of saturation had been reached whereby categories were considered sufficiently dense, and data collection no longer generated new leads (Charmaz & Liska, 2013).

To guarantee the reliability of the interviews in this study, these were audio-recorded and later transcribed. First, annotations were made on the standard concepts found among the transcripts. Next, the interview transcripts were reviewed and independently coded. Then, the codes were arranged and organised, resulting in a list of core categories related to transitioning to a CE system through IS. Codification resulted in a list of core categories related to

potential collaboration in IS and the links among them. The codes developed were further transformed into data analysed through computer-assisted qualitative data analysis software (CAQDAS).

The CAQDAS can assist during qualitative analysis regarding project management and data organisation, staying close to the data, exploring, coding, retrieving the data, seeking, and inquiring about building propositions and theorising. When utilised methodically, CAQDAS may help with continuity and promote transparency and methodological rigour and is commonly used in qualitative research to understand the connections between several responses (Saunders et al., 2009).

3.3.2 Focus group for the transition agenda

The transition agenda allows the stakeholders and pathways defined in the transition arenas to establish the strategies that will help to facilitate the transition. To this end, the stakeholders are asked, according to the transition pathways, to develop what they believe are the strategies that should be set in a transition agenda. Qualitative methods such as a focus group and a questionnaire were used to obtain a consensus on the strategies.

The focus group organised in the Basque Country (Spain) discussed the IS strategies that should be set for a transition. The region was selected as it is amongst Spain's most industrialised, with a high proportion of small and medium-sized businesses, making them an excellent standard reference for further generalisation (Ormazabal et al., 2018). Likewise, making them more aware of setting strategies and holding relationships with internal and external stakeholders.

A focus group was selected as one of the research methods to answer the research question for this study as it is particularly appropriate for exploratory analyses, and they provide researchers with a broader range of information (Hennink & Leavy, 2015). This research method focuses on a particular issue through the interactions and responses amongst participants to maintain the focus and facilitate discussion (Carson et al., 2011). The focus group allowed researchers' theoretical knowledge combined with practitioners' experience.

The participants were selected because they have expertise in IS-related activities to discuss and share their views (Krueger & Casey, 2015). Table 9 contains the main characteristics of the participants selected due to their expertise.

Table 9. Description of the participants

Stakeholder category	Role within the organisation	Type of organisation
Business	Manager environmental affairs	Bus and coach manufacturer
	Co-founder	Circular start-up
	Regional director	Waste management
	Innovation manager	Machinery manufacturer
	Manager	Consultancy
	Co-founder	Circular start-up
	CE innovation advisor	Holding company
	Manager	Consultancy
Business association	Managing director	Environmental cluster
	Program senior manager	Corporate social responsibility cluster
Foundation	Manager	Climate change
	Managing director	Environment
	Director	Climate change
Local and regional administration and agencies	Business Development Advisors	City Government
	Manager	Waste management
	Director	Circular economy department
	Policymaker	Provincial government
Research institution	Scholar	University
	Scholar	Innovation Centre
Social organisation	Project managers	Social Enterprise

Participants were invited to discuss the IS strategies that should be implemented for transitioning towards this system from the perspective of three pathways: organisational, waste, and resources as defined in the transition arena to produce value from waste (Fraccascia et al., 2019). These pathways were used in the focus group to grasp the main findings when discussing strategies for inter-organisational waste-to-resource management in a transition (Aid et al., 2017; F. F. de Souza et al., 2020; Rincon-Moreno et al., 2020).

Fifty-three experts were invited to participate in the focus group, and 25 were accepted (a 47% acceptance rate). The focus group consisted of businesses (8), business associations (3), foundations (3), local and regional administrations and agencies (5), research institutions (4), and social organisations (2) in the Basque Country. The participants were divided into four groups, considering their profile, age, and experience to ensure diversity in each group (Prieto-Sandoval et al., 2019). Each group had at least one male, one female, one researcher, one practitioner, one businessperson, and one policymaker. Also, each of these groups was guided by a facilitator who has been a practitioner/researcher in CE.

The focus group was organised as an online workshop to generate interaction to facilitate different stakeholders' attendance and record interactive discussions between participants (Carson et al., 2011; Prieto-Sandoval et al., 2019). The focus groups occurred in real-time through video-conference software, which requires participants to join at the same prearranged time. The responses collected from the workshop were recorded through an online visual collaboration platform for teamwork. During the online workshop, three activities were completed:

A. The facilitators briefly presented the IS perspective on CE, the TM framework, and how to build the strategy for this transition with multiple stakeholders. This activity took 15 min.
B. This activity was designed to stimulate self-reflection and facilitate socialisation among them by inquiring about their strategies to create changes in established structures such as institutions, regulations, finances, or physical structures systems relevant to implementing IS

through the three pathways. The participants were split into four groups and taken to breakout rooms to facilitate the discussion by setting up more minor groups. This activity took 40 min.

C. The last activity was moving toward thinking about the strategies the groups had drawn in the previous exercise. Again, all four groups were gathered in the same virtual room and were requested to elaborate on the strategies that might sound similar by the researcher who grouped them to avoid duplicates. This task aimed to make participants develop a new awareness of their context's external and internal factors. This activity took 30 min.

During the focus group, more than 100 strategies were initially collected. However, in the group session wherein all the strategies from the four groups were discussed within the same virtual room, some plans were written down in different words but with the same meaning, and others were nearly identical. In that case, facilitators removed duplicates with participants' help who were asked for clarification if needed, except for the ones that seemed similar, in which case no assistance was required. The final number of strategies was reduced to 58 of the 100 strategies collected from the stakeholders.

Though the online focus groups were more efficient for prompting spontaneous responses and interactions (Lijadi & van Schalkwyk, 2015), the strategies were not thoroughly discussed by the participants due to time constrain, which prevented them from reaching a consensus. As a result, 58 IS strategies collected and discussed in the focus group were not prioritised according to their relevance in a transition. Hence, it was necessary to rate stakeholders' level of agreement on the 58 strategies through a questionnaire sent to each of them to reach a consensus.

The questionnaire helps identify the notions and basis for prioritisation (Malhotra & Grover, 1998) and develop an understanding of topics such as IS. The questionnaire was created using Google forms as a data collection source. The questionnaire also allows for data collection in a flexible, efficient, and generalisable manner (Schutt, 2018). Online data collection provides several advantages, including lower costs, the convenience of data entry, format

flexibility and control, and a simple format to gain recipient acceptability (Granello & Wheaton, 2004). Eighteen participants completed the questionnaire, which made it possible for this research to check the validity of the IS strategies for transitioning towards a CE. In the questionnaire, on a 5-point Likert scale, stakeholders were asked about the strategies resulting from the focus group discussion. They were requested to indicate their degree of agreement on strategies' relevance to be implemented in the short and medium term.

Using Microsoft Office Excel 2019, the mean value and the standard deviation of the scores awarded to each strategy to rate the relevance of the strategies to the respondents (Saunders et al., 2009). This thesis judged high consensus for a strategy to be considered when the total participant mean degree of agreement was four on the Likert scale (Kay et al., 2018). Furthermore, at least 70% of participants rated it as four or above (Hassannejad et al., 2016). Recommendations with a mean degree of agreement of 3.5 were considered to have moderate consensus (Barbier et al., 2022). If the total mean degree of agreement was less than 3.5, no agreement was regarded to have been established.

3.3.3 Semi-structured interviews for the transition experiments

Once the agenda and its respective strategies have been determined, it is essential to know how these strategies might be implemented in activities that will impact the short term. In that sense, it is vital to understand the actions carried out by the stakeholders according to the three pathways. Qualitative data gathered through semi-structured group interviews are a rich source of information (Saunders et al., 2009). This data-gathering approach is beneficial for understanding the study setting and the processes in prior TM rounds. Therefore, semi-structured interviews were used as a qualitative data collection technique for acquiring and analysing data concerning the research topic (Charmaz & Liska, 2013).

Semi-structured interviews were performed with 19 stakeholders into six categories to gather insights into how different stakeholders deploy CE

strategies in collaboration. Following Ghinoi, Silvestri, & Steiner's (2020) six types of stakeholders for supporting the CE according to their primary organisational activities, including business (5), business associations (3), foundations (3), local and regional administrations and agencies (3), research institutions (3), and social organisations (2) as detailed in Table 10.

Table 10. Overview interviewees

Stakeholder category	Role	Organisation
Business	Manager Innovation	Machinery manufacturer
	Co-founder	Circular start-up
	Advisor CE innovation	Holding company
	Manager environmental affairs	Bus and coach manufacturer
	Managing director	Waste management
Business association	Program senior manager	Corporate social responsibility cluster
	Managing director	Circular economy cluster
	Managing director	Environmental cluster
Foundation	Managing director	Environment
	Managing director	Waste management
	Manager	Climate change
Local and regional administration and agencies	Advisor Business Development	City Government
	Policymaker	Provincial government
	Advisor Business Development	City Government
Research institutions	Scholar	Research institution
	Scholar	University
	Scholar	University

Stakeholder category	Role	Organisation
Social organisations	Project leader	Social Enterprise
	Project Manager	Student Union

The goal of this type of interview is to learn about interviewees' experiences in organisations in a focused and detailed manner, revealing perspectives, feelings, intentions, and actions, as well as the context and organisation of their activities, to understand better the reality within organisations (Saunders et al., 2009). Since this thesis seeks new insights on how specific experiments and actions can be deepened, broadened or upscaled towards a transition. Specifically, the stakeholders were asked about the activities centred on sharing infrastructures and by-products to increase resource efficiency and value creation from waste.

Then, explanation building was used as a deductively based analytical procedure to analyse the data. To ensure the accuracy of the data in this study, two researchers conducted the interviews, audio-recorded and then transcribed. The transcripts of the interviews were checked and categorised independently. An explanation building was a deductively based analytical approach to testing a theoretical proposition, albeit iterative (Yin, 2003). An attempt to build an explanation while collecting and analysing data was made by initially matching some categories derived from previous studies and literature (F. F. de Souza et al., 2020) to construct the transition experiments section.

The coding helped compare initial categories and further iterate until a satisfactory explanation is derived for relationships between activities and stakeholders (Yin, 2003). The codes were then analysed through the CAQDAS software, widely used in qualitative research to investigate the relationships between multiple responses (Saunders et al., 2009). The CAQDAS can assist during qualitative analysis regarding project management and data organisation, staying close to the data, exploring, coding, retrieving the data, seeking, and inquiring about building propositions and theorising. When utilised methodically, CAQDAS may help with continuity and promote transparency

and methodological rigour and is commonly used in qualitative research to understand the connections between several responses (Saunders et al., 2009), as in this thesis.

3.3.4 Semi-structured interviews and surveys to monitor the transition

Finally, the TM framework ends its four-cycle process with transition monitoring. This part of the transition reflects the previous steps based on the prior results by evaluating the experiments, as they are the outcomes of the steps followed sequentially in the TM framework. Indicators guarantee simplicity and effectiveness in tracking progress in a transition (European Commission, 2018; Geng et al., 2013; Llorente-González & Vence, 2019). Hence, this thesis carried out an exploratory study to propose indicators to track progress in the transition. The exploratory research offered a more detailed view of the subject to explore a problem and gather information to build the hypothesis (Yin, 2015).

A mix of research methods (e.g. semi-structured interviews and surveys) to seek the suitability of indicators to track progress in the transition were applied, as Rossi et al. (2020) suggested. A semi-structured interview method was used as a data gathering tool to determine which indicators were suitable for assessing the experiments in the transition. Semi-structured interviews were used to ask stakeholders how they would evaluate the experiments. The selection of this qualitative interview research approach was to gain information about the experiences of stakeholders (DiCicco-Bloom & Crabree, 2006).

The semi-structured interviews were carried out with the different stakeholders of the transition. However, the stakeholders do not possess a robust baseline database monitoring their progress in a transition; yet they suggested some indicators. Furthermore, in the absence of concrete indicators, as no clear pattern of indicators and their calculation was found from stakeholders as they stressed, this thesis proposes indicators based on governance frameworks known in the literature that attempt to measure progress in symbiosis activities. Thorough desktop research was carried out to filter the most comprehensive indicators to assess the experiments to track the progress in a transition.

Most indicators must comprise critical variables: renewable inputs, upcycled materials and recycled components, sustainable inputs, and job creation (Di Maio et al., 2017; Linder, Sarasin and van Loon, 2017). Also, the set of indicators must follow the RACER criteria (relevant, acceptable, credible, easy, robust) for evaluating the appropriateness of these indicators (European Commission, 2018; Saidani et al., 2019). Once the indicators were adapted, their suitability in the transition was determined. This step was done through exploratory surveys to gather all the information required to calculate and analyse actions. This survey helps identify the notions of and basis for measuring and understanding a topic in the early stages of research (Malhotra & Grover, 1998).

A questionnaire was developed and sent to be completed online to several stakeholders, most of whom were companies representing various industrial sectors in the Basque Country, Spain, as they promoted the most significant number of experiments. Seventeen respondents completed the questionnaire; the respondents were the people in charge of gathering data, making it possible for this research to check the appropriateness of the indicators.

3.4 PHASE 3: Verification of the framework

Typically, how transition processes are analysed has been in the form of comparative meta-analyses, case studies, and surveys (Köhler et al., 2019). For the verification phase of the TM framework, the case study approach will be used as it reconstructs transition processes, leading to a better knowledge and explanation of transition dynamics (Köhler et al., 2019). Case studies are a well-accepted method of inducing theory from qualitative material buried in practice (Yin, 2003). This process aims to compare the Basque Country's TM framework to the results of the Humber region during and after the NISP, considering the stakeholders, paths, strategies, experiments, and indicators that may aid a transition. Given the novelty and emergence of industries engaging in initiatives related to an IS within a CE, case studies are thought ideal for investigating this phenomenon.

Consequently, the network of industries surrounding the Humber region in the United Kingdom (UK) was chosen as a case study to verify the empirical evidence gathered in the Basque country region and to infer that this evidence can be extrapolated to other contexts working on a transition. The Humber region is one of the UK's most important energy centres, with significant energy generating facilities and infrastructure and new investment in large-scale renewable energy technologies ranging from offshore wind to biofuels (Cervo et al., 2020).

In the region, a national but locally provided initiative aiming at providing the collaborative knowledge and networking resources required to facilitate resource exchanges amongst sectors across the UK, named NISP (National Industrial Symbiosis Programme), rose to prominence (Jensen et al., 2012). The Humber Industrial Symbiosis Programme (HISP) was an effort to spark the adoption of NISP in other parts of the UK, as well as the completion of smaller projects in the Humber area (Cervo et al., 2020).

3.4.1 Case study

The case study's method is based on many sources and data gathering approaches, including desktop research, semi-structured interviews with stakeholders, and other informal collaboration via talks and emails. Documentary secondary data were employed in this verification that simultaneously gathered primary data. To gain knowledge of the Humber region's initiatives, documents such as sustainability agendas and environmental programs were analysed to collect information about IS over the last ten years.

Then, this thesis collects primary data from interviews with stakeholders conducted via a snowball sampling approach (Browne, 2005). Initial contact with regional stakeholders found that data were difficult to get due to commercial sensitivity and a lack of relevant publicly available information. Furthermore, the region is distinguished by branch offices of giant multinational corporations whose headquarters or key decision-makers are situated elsewhere. Given this background, snowball sampling was selected as an appropriate

strategy for accessing participants' social networks to target specific groups that would otherwise be hidden or unreachable.

Using a snowball sampling technique has limitations, such as the sample population's bias and the representativeness of results. However, it did allow for the finalisation of eight semi-structured interviews with major regional industrial and political stakeholders over two months (Table 11), which would not have been possible otherwise.

Table 11. Overview interviewees

Stakeholder type	Role	Organisation type
Business	Environmental manager	Chemical
	R&D manager	Manufacturing
	Company Manager	Services
	Director	Renewable energy
Business association	Program Manager and North East Energy Hub board member	Services
Local and regional administration and agencies	Climate Change Manager	Services
Research institutions	Senior Research Fellow	Services
	Lecturer	Services

This guarantees that the information gathered is similar and allows an interviewer to pursue an intriguing line of questions (Kvale & Brinkmann, 2009). The purpose of this type of interview is to learn about interviewees' organisational experiences in a focused and detailed manner, revealing perspectives, feelings, intentions, and actions, as well as the context and organisation of their activities, to better understand the reality within organisations (Saunders et al., 2009). Stakeholders were questioned about efforts centred on by-products to promote resource efficiency and value creation from waste.

The interviews in this study were recorded and subsequently transcribed to ensure the accuracy of the data, and the interview transcripts were reviewed and classified separately. An explanation-building strategy, albeit iterative, was utilised as a deductively based analytical way to evaluate a theoretical notion (Yin, 2003). While gathering and analysing data, an attempt was made to

construct an explanation by initially matching specific categories obtained from prior research and literature to develop a transition towards CE (F. F. de Souza et al., 2020).

The coding approach produced results that aided in comparing initial categories and iterating this process until a satisfying explanation for links between IS activities, and stakeholders was obtained (Yin, 2003). The created codes were then analysed using CAQDAS software (Appendix E). The software is widely used in qualitative research to investigate the relationships between multiple responses (Saunders et al., 2009) to seek new insights on how experiments can be deepened, broadened, or upscaled to a cleaner mode of production.

4

System boundary and development of the Transition Management Framework

This chapter presents the steps to shape the TM framework's process to implement IS towards a CE system. As explained in the methodology section, the TM is a four-cycle process that sequentially presents the results until the transition monitoring stage is reached. The corresponding results are presented in this chapter.

4.1 Introduction

TM may be classified as participatory governance because the change process includes steps such as issue formulation, imagining future paths, and trying and learning (Grin et al., 2010). The TM framework (Figure 7) presented in this thesis is about TM deployment (for example, politics of sustainability transitions, power dynamics in participatory forums, and inclusion of stakeholders) to implement an orderly transition through a four-cycle process (Wittmayer & Loorbach, 2016). There is no step-by-step guide to ensure a successful transition towards an IS model. In this section, we will further explain the contribution of each method in the development phase to obtain the insights needed to use the TM framework.

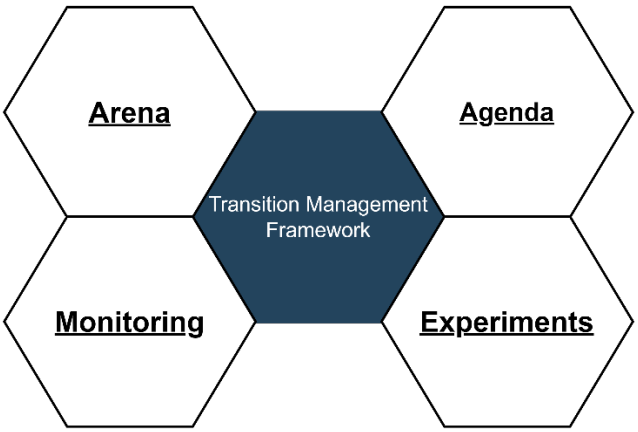


Figure 7. Transition management framework (Adapted from Loorbach et al., 2017)

4.2 System boundary

The successful transition towards an IS will depend on capacities to capitalise on complementarities and collaborate on developing a shared network identity among partners (Magnusson et al., 2019). The participants in these iterative processes meet in a virtual network (in the transition arena) to observe potential synergies (Loorbach et al., 2017; Loorbach & Rotmans, 2010). The networks are made up of companies that could either make joint resource

acquisitions or form a broad network that could oversee a common waste management consortium (Velenturf, 2017).

4.2.1 Waste-to-resource network

A theoretical network of waste-to-resource exchanges is described that will help to understand the networks wherein the TM framework is deployed. An industrial park (Figure 8) with diverse companies that would allow a symbiosis to happen is selected to identify whether there are potential synergies among companies. These networks were created due to their possible creation of synergies in an IS. Some networks were made up of companies that could either make joint resource acquisitions or form a broad network that could oversee a joint waste management consortium (Velenturf, 2017).

Figure 8. Industrial Park

Some of the companies within the industrial park are related to food, automobile, carpentry, construction, glassware, plumbing, training, home and decoration, printing, information technology, engineering, electrical

installations, machining, furniture, fashion and accessories, computer security, industrial services, telecommunications, and transport.

Four networks are created based on the waste companies could use as resources within the industrial park (Table 12). The companies, which generated waste suitable to be considered in a synergy, were called donors, and the companies with the potential to receive waste as a resource were named recipients. For instance, "paper and cardboard" or "paper and cardboard packaging" waste can be used as "fibre paste obtained from recycled paper or cardboard". The "tyres out of use" obtained from vehicles can replace "embankments", and it has been suggested that the "wooden pallet (good conditions and damaged)" can have different uses, such as fuel, tables, cabinets, and pallets.

Table 12. Waste networks

	Lead Batteries Network	Paper and Cardboard Packaging Network	Tyres Out of Use Network	Wooden Pallet Network
Companies	31	28	20	28
Recipients	0	0	3	21
Donors	30	27	16	6

According to these theoretical networks, most of them seem unlikely to carry out a waste-to-resource exchange due to an apparent necessity to transform some materials before their new use (e.g., paper cardboard into fibre paste). A lack of knowledge about what kind of waste can be transformed into resources usually happens in manufacturing companies (Kerdlap et al., 2019).

Overall, these sorts of exchanges would have limited information on resources that have left their organisations' boundaries but are still likely to remain in the circularity system, as indicated by the results. Companies cannot undertake this task independently as it could generate a burden rather than a strategic advantage. This uncertainty is a problem in procuring secondary materials as imperfect information limits the value for local symbiosis (Figge & Thorpe, 2019).

Afterwards, two separate industrial clusters (textile and recycling) with the scope of promoting the transition were found for the analysis. Table 13 summarises the objectives of the clusters set by the public administration.

Table 13. Features of the industrial clusters

	Recycling cluster	**Textile cluster**
Members	Companies, research centres and universities, foundations, and environmental consulting firms	Fashion brands, accessory brands, and R+D bodies
Main objectives	Promote the reuse and creation of new recycled products and efficient consumption of materials through research and development (R+D) Explore new employment niches in reuse and recycling, enhancing the importance of the circular economy. Promotion of symbiosis through innovation.	Support environmentally friendly policies, design, and marketing processes to ensure sustainable fashion. Foster innovation, entrepreneurship, and the creation of new products. Serve as nexus for communication and participation between the different agents within the sector and as a collaboration platform.

As stated above, the regional government has issued a CE strategy for the region. This strategy primarily focuses on industrial clusters to ensure added value and benefits are delivered among their members through continuous cooperation. This strategy makes it feasible to integrate IS (Baldassarre et al., 2019). The clusters are known for the involvement of different stakeholders that plays a crucial role in creating cooperation and communication among companies and other stakeholders because of their highly industrialised output

and the greater awareness of such opportunities (Ormazabal et al., 2016; Rincón-Moreno et al., 2021).

Finally, the system boundary of this thesis should include the subsystems that link the other subsystems that treat waste and the subsystems that convert raw materials into waste to fully account for the effects of recirculating materials into upstream subsystems (Cobo et al., 2018). Thus, a waste management organisation that deals with waste by collecting, separating, and treating waste is analysed. The waste management organisation serves approximately 2000 companies in industrial parks and generates the data of these industrial areas. So, a particular focus was given to waste collection in industrial areas (Figure 9) grouped by industrial parks in five years (2014-2018), representing the different waste streams.

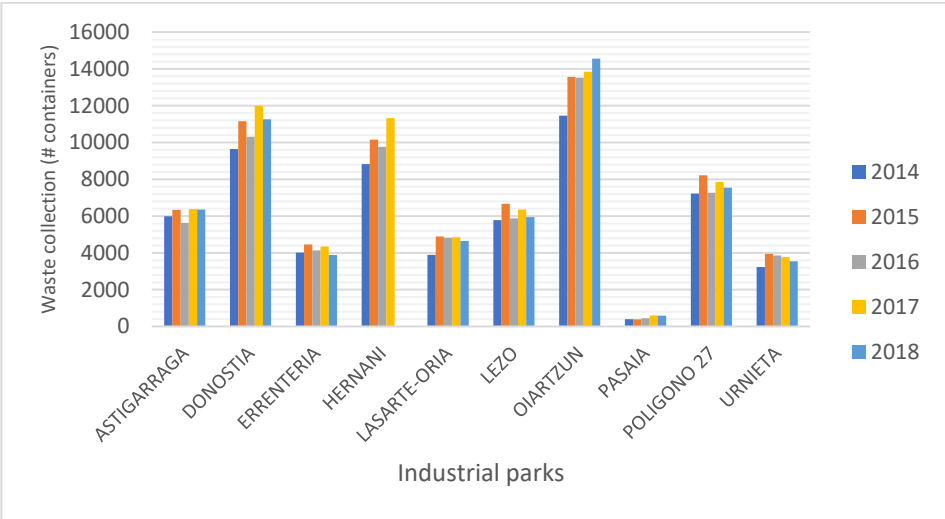


Figure 9. Number of wastes collected in industrial parks

Under these circumstances, the evolution of industrial waste management is analysed to observe whether the proper conditions to develop IS to sprout in the region are met through the analysis of waste collection. This thesis has focused on three waste streams, which have been of most interest: biowaste, non-compostable organic, from now on organic, and inert due to its evaluation in

volume and because it is a fraction with a high environmental impact (not recoverable).

Figure 10 shows the evolution of the number of times a waste stream has been collected, corresponding to the three most relevant fractions studied (bio-waste, inert, organic) during the years of the study (2014-2018) in each of the ten industrial parks. As shown in Figure 10, these three fractions over the time-span period studied represent significant operations carried out with the waste streams managed in the industrial parks.

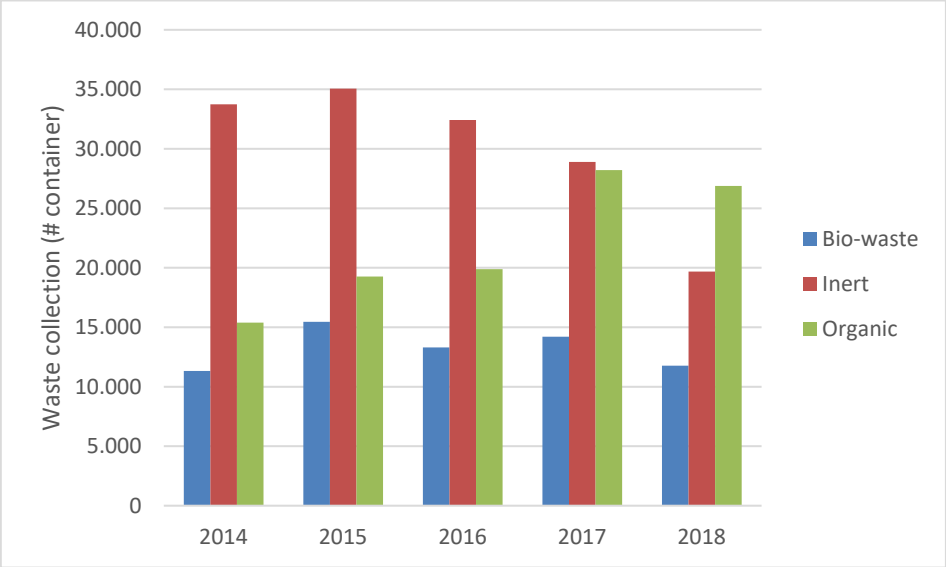


Figure 10. Number of collections for different waste streams

Neither a characterisation of each waste stream nor an assessment of its quality has been done. The fact that waste streams in the different industrial parks analysed are being collected constantly throughout the years offers an opportunity for integrating industrial waste management into resource management. The findings of this study showed that every industrial park report waste generation. This finding could be used to more accurately observe how waste management can create synergies boosted by the geographical proximity of the industrial parks and clusters (Freitas & Magrini, 2017).

This information is of particular interest because it means that when information about how companies manage their collections is available. This information would, in turn, create a reliable waste as a resource model (i.e. a secondary material market) that could be sustained over time (Schreck & Wagner, 2017). This data could be relevant for companies where the waste management sector would participate in expanding its role as a facilitator for managing resources (Aid et al., 2017) or as a supplier of high-quality waste in an IS (Prosman & Wæhrens, 2019).

4.3 Transition arena

The transition arena created within the system boundary must provide potential synergies whereby waste and by-products could theoretically be recaptured in other product supply chains. Although these sorts of exchanges, including methods and economic and environmental benefits, are very present in the literature, further aspects, such as governance of the IS, are frequently neglected (Mortensen & Kørnøv, 2019; Walls & Paquin, 2015). This governance usually relies on stakeholders.

One of the most relevant aspects of the transition arena is to find stakeholders to carry out the transition. Many stakeholders can participate in the transition but selecting such stakeholders with a strong track record of initiatives is crucial in facilitating the transition. Hence, the different stakeholders and their roles within the system boundaries are described in this section. Then, the pathways that summarise the challenges stakeholders need to address to make the transition possible are introduced.

4.3.1 Stakeholders, pathways, and roles

This section analyses the interviewees' responses (Appendix A) to understand how the stakeholders may help facilitate the transition through their roles and the pathway they should follow. Stakeholders were identified within the system boundaries. IS-related activities characterise these stakeholders. Several of them are recognised for their leadership in sustainable initiatives. For example, in this thesis, the **local administration** has been identified as one of the

stakeholders that aim to create demand for materials from waste by involving the economic sectors with the most significant potential to carry out this transformation (Table 14). Namely, it has been reported in the literature that while organising new synergies, the role of public bodies in funding and providing support for innovative processes is critical to enhancing collaborative partnerships (Mortensen & Kørnøv, 2019).

Table 14. Stakeholders and their roles

Stakeholder	Role
Local administration	Manages networks and promotes collaboration networks opportunities
Foundation	Raising awareness among companies and society about such benefits Promote symbiotic opportunities.
Businesses	Collaboration with research institutions, other companies, and local administration
Research institution	Serves as a bridge for public administrations and businesses. Joint research grants with public administration.
Social organisations (e.g. NGOs)	Delivers insights from working with civil society Offers trust to the stakeholders
Business associations	Support to businesses in organisational issues

Likewise, another stakeholder pivotal to the transition is a **foundation** fully committed to supporting symbiosis opportunities by serving as the waste manager and creating a value proposition by eliminating the concept of waste within the textile sector. This stakeholder is an intermediary agent seeking collaboration between companies with the same problems or synergies. For instance, they supply waste to a stakeholder to create new furniture sold to regular customers. Also, they partner with a company that supplies 'waste' to the stakeholder, turning it into covers to protect vehicle seats. This role enables it to

provide a second use for these materials that otherwise would have been discarded when a financial return is not clear yet.

Another stakeholder defined for this thesis is **businesses** such as a company that recycle plastic bottles and transforms them into different high-end products. They opted for a large-scale project in which they collaborated with universities, technology centres, and companies in the area. This close collaboration with these stakeholders also gave rise to spinoff projects. This stakeholder also owns a recycling plant, a processing plant for the waste they generate in their processes, and one cogeneration plant, which allows them to develop their thermal and electrical energy sold to the grid. It is also proactive in leveraging symbiosis opportunities.

In particular, the specific knowledge of this stakeholder by creating these networks highlights the relevance of having several capacities to capture value from IS initiatives to support a transition (Ghinoi et al., 2020). Another stakeholder related to the business side is a company that reaches the industry with IS projects but is supported by the administrations, as seen in other countries (Cervo et al., 2020; Neves, Godina, Azevedo, et al., 2019).

On the other hand, stakeholders focused on research, such as **research institutions** on aspects related to a sustainability transition, are considered for this thesis. Universities and research centres as this type of stakeholders support knowledge dissemination, promote circular regeneration by collaborating with local communities, facilitating the implementation of knowledge-based systems, and mobilising human and economic resources to promote a culture of reduction, reuse, and recycling (Kalmykova et al., 2018). As part of the CE 2030, this stakeholder aims to reach industries and civil society to close the loop. This stakeholder collaborates with a steel company that developed a recycling system for their products and by-products to serve as suppliers for companies in the same holding. One of the outcomes was that the packaging could be reused and reduced waste generated.

Although the involvement of different stakeholders plays a crucial role in creating cooperation and communication among companies and other stakeholders (Table 13), there are still some shortcomings in speeding up

collaboration (Rincon-Moreno et al., 2020). This shortcoming inhibits the entire deployment and implementation of IS in the region (Rincon-Moreno et al., 2020), regardless of being a highly industrialised and highly aware of such opportunities (Ormazabal et al., 2016; Rincón-Moreno et al., 2021). Public knowledge and comprehension of IS remain low among other stakeholder groups.

For instance, some stakeholders might be identified as part of the Snowball Sampling Approach (Section 3.3.1) but were not actively a part of this network of stakeholders that should be questioned about these concerns. This active role is most likely an unresolved issue, as stakeholder engagement and collaboration are critical for the development of the transition (Ghinoi et al., 2020). One of these stakeholders is a **social organisation** such as NGOs involved in environmental issues, which may be interested in waste-resource exchange projects. Several stakeholders mentioned this type of stakeholder as their insights might bring value in improving the responsiveness of other stakeholders by serving as a bridge and building trust between the parties.

Similarly, as an extension of businesses, there are **business associations**. This stakeholder was identified, but its role is more related to working in public-private partnerships behind the scenes without interfering in the physical exchange of materials and energy. This stakeholder lobbies on behalf of their members for public policies or funding through lobbying with central bodies such as public administrations. Although they know the crucial aspects of IS, their role is more related to an administrative environment. Given the conceptual underpinnings discussed above, it is anticipated that the transition will necessitate the involvement of all these stakeholders at various institutional and regional levels, as it requires the development of deep and harmonious relationships to achieve mutually beneficial progress and competitiveness (Domenech et al., 2019).

As detailed above and summarised in Table 14, six stakeholders were defined as part of the transition arena as they have collaborated on multiple fronts related to IS. This emphasis on inter-organisational linkages highlights the relevance of stakeholder networks and the possible involvement of policymakers in

implementing IS-based solutions. As shown in this thesis, the stakeholder and network views emphasise the need for multiple skills to incorporate different stakeholders in network interactions (Abreu & Ceglia, 2018). This stakeholder engagement might result in accepting common strategies to transition to an IS system (Kirchherr et al., 2018).

Nevertheless, different perspectives or pathways in a transition might emerge, resulting in typologies that differ in terms of the features they stress. These pathways may facilitate the transition. Having mentioned the stakeholders who control resources, those who deliver a value proposition around waste-to-resource transformation or help create a value network to promote symbiosis, the following section summarises the main pathways for developing the transition. The stakeholders' responses identified the pathways on the types of solutions needed to carry out the transition. These were grouped into three clusters with similar characteristics in facilitating the transition. Cramer, 2020c has also highlighted these pathways; Herczeg et al., 2018; Mortensen & Kørnøv, 2019; Prosman & Wæhrens, 2019, in which, in addition to the problems to be solved in waste and resource management, the organisational aspect plays a crucial role in the creation of synergies and cooperation in networks of IS.

The transition pathways broadly represent the challenges of transitioning toward an IS (Domenech et al., 2019; Saavedra et al., 2018) and facilitate forming stakeholder partnerships. These pathways also represent stakeholders' direction to realign objectives and facilitate the transition (Geels & Schot, 2010). Three transition pathways were identified on which the transition towards an IS network should be developed according to stakeholders' responses (Table 15).

Table 15. Pathways to guide the transition

Organisational	Waste	Resource
Funding (grants & economic incentive)	Waste market	Remanufacturing
Partnerships	Landfill diversion	Research
Procurement	Recovery	Innovation in secondary materials

Also, based on the responses provided by stakeholders, some key aspects need to be covered in each of the pathways to develop waste-to-resource strategies and the generation of IS initiatives. Consequently, the first group, **"organisational management"**, refers to the problems related to establishing synergistic relations based on the social dynamics of companies. An organisational pathway has been regarded as an issue with administration regarding technology aid and information monitoring that could potentially facilitate formal agreements, freeing the formation of new relationships in the IS process.

According to (Mortensen & Kørnøv, 2019), this organisational pathway could potentially damage formal agreements and, therefore, restrain the organisation of new relations. Low et al. (2018) and Walls & Paquin (2015) have stressed the importance of an organisational pathway. They refer to this pathway as non-technical barriers, such as a lack of trust and collaboration among participating enterprises, knowledge gaps, and rigid or non-existent environmental rules, which must be addressed from a broader viewpoint.

One is the **partnership** between public-private parties relying on government-funded sounding support. Some stakeholders responded that the **funding** aspect is still essential. They stated that local government assistance is fundamental to facilitating synergies. The local administration is constantly mapping initiatives and needs among companies to search for value creation by eliminating the concept of waste. They do so by financing, advising, and disseminating knowledge within business networks in the energy, built environment, metals, plastics, and electronics sectors.

Public administrations seem critical in helping them carry out these projects with companies, especially when IS initiatives require much cooperation to explore new synergies. The local administration considers the inclusion of the industries based on their raw materials use, the volume of waste generation throughout its activities, and the capacity for the reincorporation or **procurement** of secondary raw materials.

This interaction might have implications for continuing this practice if publicly funded grants or incentives suddenly stop promoting these partnerships due to tensions between conventional ways of doing business or public-private partnership disruptions (Panwar & Niesten, 2020; Velenturf, 2017). So, a factor that may influence the generation of IS initiatives is the lack of strategic planning for companies that sometimes see it as a requirement to access aid instead of a competitive advantage (Prieto-Sandoval et al., 2019).

Authors such as Esposito et al. (2018) suggest that this challenge for both businesses and policymakers must be dealt with organisational designs that facilitate the adoption of this strategy as they work with different stakeholders. Addressing these issues would undoubtedly help strengthen organisational management factors towards implementing the IS (Abreu & Ceglia, 2018). Thus, these results suggest that the organisational aspect in a transition towards a circular business model innovation through an IS perspective might help advance the transition (Baldassarre et al., 2019; Hofmann & Jaeger-Erben, 2020).

The second clustered group, **"waste management"**, recognises the lack of leadership of waste management companies in leading other businesses towards a model where waste is seen as a resource. A waste pathway focusing on the quality of recovered material rather than the amount of garbage processed will be critical to capitalise on establishing synergies among businesses (Corona et al., 2019). Some stakeholders expressed interest in undertaking activities, such as goods distribution or joint purchases. Some authors claim that waste management companies should expand their role toward new business models around IS to a more integrated sustainable service to create value for their customers, such as a market maker for secondary materials or a **waste market** (Aid et al., 2017).

A shift to new business models from waste management companies targeting **landfill diversion** to focus on the quality of the recovered material instead of the amount of waste processed will be essential for the transition (Corona et al., 2019). Although Domenech et al. (2019) highlight companies' critical role in creating a regional symbiosis, they also discuss the institution's role in creating a level-playing field for industries to **recover waste**. In this

second pathway, the absence of clear frameworks to encourage IS principles' integration may harness opportunities in creating synergies among companies was also acknowledged.

The third group of responses clustered as "**resource management**" points out a low synchronisation in developing guidelines or procedures for managing resources as well as a high centralisation in logistics, which makes it challenging to support the initiation process for resource partnerships in a potential regional symbiosis (Velenturf, 2017). In that regard, finding partners to create value will largely depend on the ability of companies to **innovate** under a model of high coordination and low centralisation to overcome this challenge (Fraccascia et al., 2019). Likewise, focusing on **research** on several topics such as recovery processes, reuse, and recycling of the product as one of the stakeholders may serve the purpose of the experimentation centre to see if there is any beneficial effect, emission reduction, or added value to businesses.

This statement proved what other studies have claimed about expanding the understanding of collaborative value creation networks within market-based environments and the strategic relevance of carrying out a transition led by other sectors (Hofmann & Jaeger-Erben, 2020; Velenturf, 2017). Moreover, re-shaping the market and re-structuring themselves by interacting with their stakeholders in the context they operate might help to transform such a complex network (Loorbach & Wijsman, 2013).

According to some stakeholders, one factor that may speed up the generation of these initiatives is the opportunities to produce new materials for new use, extend the life of resources, or obtain high-value recycling products via **remanufacturing**. However, they claim that more waste-to-resource exchanges need several actors at stake in the value chain: the producer, suppliers, consumers, or even the carriers.

Participating in inter-organisational relationships between businesses would allow companies to allocate IS resources to coordinate and encourage cooperation (Hofmann & Jaeger-Erben, 2020; Walls & Paquin, 2015). This high need for coordination coupled with a decentralised control of waste to resource

exchanges might help create value in symbiotic relations to connect all types of organisations to trade wastes and by-products to facilitate the transition (Fraccascia et al., 2019; Kerdlap et al., 2019).

Based on the observations made in the case study, the stakeholders are aware of the strategic advantages of implementing IS initiatives, especially when the purpose is to minimise downcycling of materials and increase the share of reused resources as proposed by IS to create added value. All the stakeholders include inter-firm cooperation and the expansion of resource sharing (Millar et al., 2019), which would eventually lead to fewer units of new materials being sourced due to resources flowing back and forth among resource users (Figge et al., 2021).

However, not a systemic level effort besides the clusters was mentioned by the stakeholders when asked about the influence of the multiple critical agents that should be more involved. One of the essential factors in making the transition possible must incorporate all the stakeholders equally. As was observed in this section, a stakeholder-based approach is critical to ensuring a transition, mainly when it is meant to be implemented through IS. In particular, a local-level focus on a transition is of the utmost importance since, on this scale, it proves less demanding to mobilise collective action to achieve circularity (Graymore et al., 2008).

4.4 Transition agenda

The second component of the TM framework is called the agenda. The agenda is built on a shared awareness of the problem's persistence, the need for a transition or drastic change, and a set of strategies to guide the envisioned transition with stakeholders.

4.4.1 Setting the strategies

The study has collected and analysed the strategies obtained in the focus group (Appendix B), collaborating with stakeholders from businesses, business associations, foundations, local and regional administration agencies, research institutions, and social organisations. Overall, it could be said that the

stakeholders have agreed on specific strategies grouped in the three pathways proposed for this study (e.g., organisational, waste, resources), such as 'green taxation' or circular public procurement. Some strategies have focused on raising awareness, changing organisational culture, and training employees on such issues. Other strategies focused on the appropriate characterisation of waste to be converted into resources and the launch of methodologies and technologies that guarantee the quality of secondary materials.

Thus, according to the participants' responses, in a transition, the three pathways of IS might help to increase the capabilities of the transition to create and deliver value through cost efficiency, such as waste management in the value chain enhanced with strategic management (F. F. de Souza et al., 2020). Similarly, the stakeholders pointed out that the different strategies must be executed collaboratively.

They stress that the strategies that are believed to help in the transition are the ones that offer necessary mechanisms that effectively guarantee that waste can be received as resources in a collaborative way (incentives, means of reuse, incorporation of secondary material, among others). This statement is also supported by evidence of companies, government agencies, and NGOs searching for synergies with each other (Geissdoerfer et al., 2017). This strategy may imply a collaborative approach to stakeholder relationships more engaged in proactive roles to an untapped source of value creation partnerships which might rival previous stakeholder engagement's focus on addressing and resolving conflicts and opposing interests (Goodman et al., 2017).

Moreover, the stakeholders highlighted the need to include the different levels of public administration (local, provincial, regional, and state), industries, and academia. Moreover, they also mentioned that the role of the consumer should play a fundamental role since their purchasing choices contribute to the transformation of the current system. This statement comes in hand with what other authors have claimed. Firms alone cannot become sustainably oriented as they merely contribute to more sustainable patterns of production and consumption within society (Loorbach & Wijsman, 2013). So, Baldassarre et al. (2019) emphasise that the complexity of a transition would require community-

based involvement in the collaboration of several stakeholders aligned in a long-term engagement to generate economic, environmental, and social value.

Although, on average, strategies of the three pathways were considered almost equally important, the resource pathway has been highlighted on average as slightly more important among these according to the ranking given by the participants (Figure 11). On a 5-point Likert scale, stakeholders were asked about the strategies resulting from the focus group discussion. They were requested to indicate their degree of agreement on strategies' relevance to be implemented in the short and medium term. This result suggests that despite the slight difference on average given to the strategies by the participants, all three pathways should play a balanced role in the transition, as mentioned before. Authors such as Boons (2009) and Loorbach & Wijsman (2013) proposed dealing with these complex issues with inter-organisational collaboration to find suitable solutions.

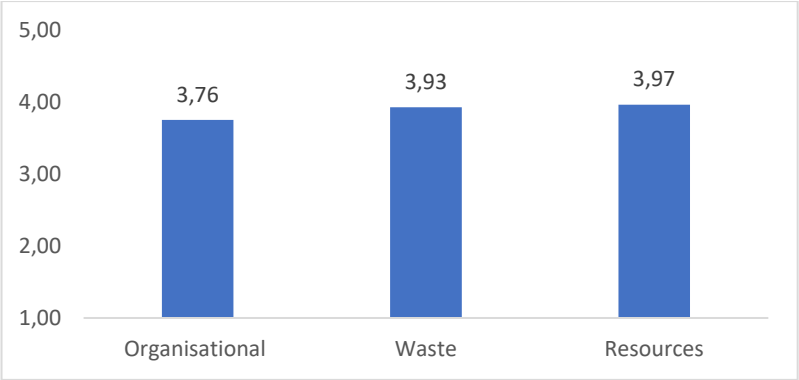


Figure 11. Strategies' relevance

Aid et al. (2017) have studied an illustrative representation of innovative inter-organisational resource management to create new value with customers and partners to address uncertainties in a transition that facilitates transition strategies in the waste management sector. Similarly, Veleva & Bodkin (2018) analyse IS in business networks to achieve a CE model through waste-free production, new product design, material reuse, and remanufacturing.

However, participants have rated some strategies as the most relevant within each type of management. For example, in the organisational pathway,

participants have estimated that nine strategies would be the most important to implement IS (Table 16). Among the nine strategies (greater than 4), the 'Establish incentives to sectors/companies by circular economy actions' was the one with the highest score (4.28 / 5).

Table 16. Organisational pathway

Strategies	Rating	Standard deviation
Establish incentives to sectors/companies for IS-related actions	4,28	0,75
Encourage innovation in technologies that allow IS value chains	4,22	0,81
Procurement of goods and services with circularity criteria	4,22	0,88
Awareness in which all links in the chain are involved (from suppliers to customers)	4,22	1,00
Precise diagnosis of existing waste, resources, and consumption associated with the different industrial sectors	4,11	0,96
Mandatory circular public procurement	4,11	1,08
Establish alliances between different agents to increase circularity	4,06	0,80
Simplification in administrative processing at the end-of-waste stage	4,06	1,11
Mapping of processes to identify critical points and improve production efficiency	4,00	0,69
Redesign with recycled materials criteria	3,94	0,80
Development of a roadmap for the transition within the organisation	3,89	0,90
Create an organisational culture that aligns sustainability and competitiveness as part of a transversal management strategy	3,89	1,02
Establish intersectoral/interindustry roundtables to diagnose synergies in nearby territories / industrial parks	3,89	1,02
Define a clear policy within the company	3,83	0,92

Strategies	Rating	Standard deviation
Visibility (rigorous information)	3,83	1,04
Increase the surveillance capabilities of new business models, training, success stories, and technical-economic viability.	3,78	0,73
Training in sustainability and circularity aspects for the entire organisation	3,78	0,88
Analysis of the initial diagnosis of the situation and study to define the actions to be taken (e.g., SWOT-CAME) aimed at the transition	3,61	1,09
Promote bottom-up and all-together communication to identify opportunities to improve competitiveness in the transition to CE	3,56	0,86
Find common spaces (of various actors or organisations) to promote creativity	3,56	1,10
Regulatory change by productive sectors	3,50	1,15
Identification and prioritisation of current stakeholders for the linear model and its evolution towards the transition to the CE	3,39	1,14
Create digital tools that report in real-time on the waste generated, the resources consumed, and the potential for recirculation	3,28	1,36
Easily accessible information tools for companies and agents on actions, news, studies	3,22	1,31
Strategic monitoring of legislative trends and state of the art in the activity and sector of the organisation	3,11	1,08
Strengthen the coordination of the waste observatory in autonomous communities and county councils	3,06	0,87
Transversal management in the different dependencies of the public administrations	3,00	1,03

In this pathway, according to the score given by the stakeholders, they agree that cooperation is of the utmost importance. Nevertheless, the strategies mentioned in this section demonstrate that establishing collaboration not necessarily indicates a physical waste-to-resource exchange but also some

agreements that would reduce uncertainties through cooperation with other stakeholders.

Strategies that deal with incentives for IS actions, innovation to generate a new value chain, public procurement, and alliances align with what other authors have observed. For example, Song & Thieme (2009) suggest a collaborative innovation in connection to specific groups such as suppliers, and Park, Duque-Hernández, & Díaz-Posada, (2018) discuss the development of IS through a management perspective to facilitate business collaboration which is a crucial feature (Baldassarre et al., 2019).

Regarding the waste pathway, it should be noted that 11 of the 21 strategies have received a score higher than 4 (Table 17); the strategy called 'Establish paths so that the waste can be reused and recycled the one with the highest score (4.50). This score would indicate that the participants consider that a relevant strategy should ensure practical inter-organisational cooperation so that waste creates synergies among companies.

Table 17. Waste pathway

Strategies	Rating	Standard deviation
Establish networks so that waste can be reused and recycled	4,50	0,62
Strengthening of green taxation that restricts waste to landfills and promotes circularity of waste	4,39	1,09
Extended producer responsibility	4,22	0,88
Eco-design to reduce waste generation	4,22	1,00
Generate a legal framework to promote valorisation through by-products	4,17	1,04
Cost of raw materials sent to landfill factored in waste management handling fees	4,06	0,73
Sorting out legal aspects of waste handling by companies	4,06	0,80

Strategies	Rating	Standard deviation
Identification, characterisation, and selection of potentially valuable material/waste fractions for future use	4,06	0,87
Expand the focus on product recall: refurbishment, reconditioning, remanufacturing	4,06	1,00
Increase the shelf life of products or use them as secondary material	4,00	1,08
Create plans to manage the separation and classification of waste to promote second use	4,00	1,14
Awareness campaigns to prevent waste	3,94	1,00
Determine the opportunity cost of recycling waste	3,94	1,00
Mapping of agents for the reuse of waste	3,89	1,08
Identification of valorisation opportunities of IS through industrial eco-parks	3,72	1,02
Digital platforms to facilitate the exchange of waste and resources	3,72	1,13
Research and technological development in the prevention plans of companies in the generation of waste	3,67	1,19
Review of waste quality standards	3,56	0,78
Provide information on available waste by organisations	3,56	1,10
Define the residue condition	3,56	1,34
Seek continuous demand	3,28	1,27

Nevertheless, the sole application of this strategy appears to fall short as all the efforts made to implement IS initiatives at a global scale or tap its potential

is still a niche strategy facing multiple challenges (Ormazabal et al., 2018; Rincon-Moreno et al., 2020). Some of the strategies with the highest score by the stakeholders show that more work is needed to be carried out successfully. The same applies to strategies linked to establishing networks for waste reuse, 'green taxation, and legal frameworks that encourage the circularity of materials, designing-out waste through extended producer responsibility and eco-design.

It appears that strategies related to treating waste as a resource are needed to be considered from a hybrid approach that will require top-down and bottom-up interventions (Sánchez Levoso et al., 2020). Each strategy suggested for the waste factor reflects what could play individual stakeholders in the transition process. Every intervention would require single contributions being added up to support the implementation of IS (Ghinoi et al., 2020). Thus, managing waste as a critical factor in the transition from a linear economy will require coordination and cooperation among multiple networks to develop new value chains and create new norms, such as accepting waste as an input (Sharma et al., 2020).

Lastly, in the resource pathway, 50% of the strategies received a rating greater than 4, showing the degree of importance given to this type of organisation factor to close the loop (Table 18). The strategy 'Tax incentives that promote the entry of recycled materials has been the one with the highest rating, which confirms that the transition can be facilitated if there are mechanisms that ensure that the waste becomes a resource.

The stakeholders considered incorporating elements that guarantee that the input of recycled materials was not the only way to transition through resource management. They also contemplated eco-design, regulatory frameworks, innovation, and reducing the reliance on critical raw materials to avoid resource depletion as part of the strategies required to support the transition. Prieto-Sandoval et al. (2019) pointed out that the valorisation of by-products also relies on technological modernisation and integration with other stakeholders to build an integrated flow of resources. These outcomes can manage or transform waste streams, such as waste managers at landfills or incineration sites (Table 18).

Table 18. Resources pathway

Strategies	Rating	Standard deviation
Tax incentives that promote the input of recycled materials	4,67	0,49
Incorporate eco-design principles to ensure recirculation of products	4,17	0,92
Development of regulatory frameworks for the application of secondary materials (e.g., regulatory measures)	4,17	1,20
Training, innovation, and development in the management of new resources	4,11	0,83
Analyse the dependence of the industrial sector on critical raw materials to find proper alternatives	4,00	0,97
Establish IS-related criteria for the selection of suppliers	3,94	0,80
Management and certification systems that guarantee circularity in production processes	3,83	0,92
The information available on material flow analysis, life cycle analysis, monitoring sensors, and value chain mapping	3,78	0,73
Studies on material alternatives in existing production processes	3,56	1,04
Databases of waste and resources available	3,44	1,15

Some authors offer insight into how waste managers may assist the transition by improving inter-organisational relationships to create and deepen the collaborative value creation network in their business approach (Aid et al., 2017; Hofmann & Jaeger-Erben, 2020). Similarly, one feasible opportunity to experiment with most of the strategies grouped in this factor suggests that waste recovery might be achieved in supply chain management, such as reverse logistics, which focuses on innovation in the business model. This approach has been displayed as a sign of commitment to policymakers and an increase in value

capture mechanism to turn waste into value on the road to competitiveness in the market (Baldassarre et al., 2019; Prieto-Sandoval, Ormazabal et al., 2018).

As observed in this study, the strategies proposed and assessed by the stakeholders invited to participate may be linked to creating inter-organisational resource management capabilities to decrease the probability of disagreements between the different value creation systems (Hofmann & Jaeger-Erben, 2020). A good selection of potential strategies to be scaled up must be collected and prioritised to develop the ground to ensure the success of the transition (Sánchez Levoso et al., 2020). Therefore, this thesis prioritises the strategies based on the consensus of a strategy to be considered when the total participant mean degree of agreement was four on the Likert scale (Kay et al., 2018). At least 70% of participants had to rate it as four or above (standard deviations of less than 1,0) (Hassannejad et al., 2016). This grading reflects a strong consensus on the strategies given among the experts to be considered relevant for the transition (Prieto-Sandoval, Ormazabal, et al., 2018).

The strategies regarded with a strong consensus are allocated in each pathway (e.g., resources, waste, and organisational), as shown in Table 19. Strategies such as "Tax incentives that promote the entry of recycled materials," "Establish networks so that waste can be reused and recycled," "Cost of raw materials sent to landfill factored in waste management handling fees", or "Establish incentives to sectors/companies for IS-related actions" are considered highly relevant to facilitate the transition.

Table 19. Most relevant strategies

Pathway (Arena)	Strategies	Rating	Standard deviation
Organisational	(S1) Establish incentives to sectors/companies for IS-related actions	4,28	0,75
	(S2) Procurement of goods and services with circularity criteria	4,22	0,88
	(S3) Establish alliances between different agents to increase synergies	4,06	0,80

Pathway (Arena)	Strategies	Rating	Standard deviation
Waste	(S4) Precise diagnosis of existing waste, resources, and consumption associated with the different industrial sectors	4,11	0,96
	(S5) Cost of raw materials sent to landfill factored in waste management handling fees	4,06	0,73
	(S6) Establish networks so that waste can be reused and recycled	4,50	0,62
	(S7) Sorting out legal aspects of waste handling by companies	4,06	0,80
	(S8) Identification, characterisation, and selection of potentially valuable material/waste fractions for future use	4,06	0,87
	(S9) Extended producer responsibility	4,22	0,88
Resources	(S10) Expand the focus on product recall: refurbishment, reconditioning and remanufacturing	4,06	1,00
	(S11) Tax incentives that promote the input of recycled materials	4,67	0,49
	(S12) Encourage innovation in technologies that allow IS value chains	4,22	0,81
	(S13) Training, innovation, and development in the management of new resources	4,11	0,83
	(S14) Incorporate eco-design principles to ensure recirculation of products	4,17	0,92

4.5 Transition experiments

This section describes different activities the stakeholders do, whether in isolation or in collaboration with other stakeholders, to create solutions to deploy IS. The experiments in this stage seek to materialise the strategic agenda elaborated with the stakeholders in the previous section. To this end, the stakeholders who proposed this agenda were consulted about how they execute projects to achieve the transition. Table 20 shows the experiments following the transition agenda strategies and the pathways (organisational, waste and resources) defined in the transition Arena. These experiments are part of the operationalisation of the TM framework (Veldhuizen, 2020) led by the different stakeholders.

4.5.1 Types of experiments

The actions mentioned by stakeholders to facilitate the transition were grouped by type of experiments. These experiments belong to the strategies developed in the transition agenda and are intended to serve as a compass for implementing the transition. A total of 20 types of experiments mentioned by the different groups of stakeholders (Appendix C) were categorised according to the kind of strategy they belong to (Table 20). Nevertheless, the strategy called "Tax incentives that promote the input of recycled materials" appears as the only one that is not mentioned in the experiments, which implies that tax incentives are not part of the practices to stimulate the creation of IS networks in their current state.

Table 20. Transition experiments in the TM

Pathway (Arena)	Strategies (Agenda)	Experiments	% Total
Organisational	(S1) Establish incentives to sectors/companies for IS-related actions	Economic incentive scheme	2,21
		Grants	1,10
	(S2) Procurement of goods and services with circularity criteria	Procurement	3,87
	(S3) Establish alliances between different agents to increase synergies	Partnerships	10,50
		Pilot project	5,52
		Workshops	3,31
	(S4) Precise diagnosis of existing waste, resources, and consumption associated with the different industrial sectors.	Methodology	6,08
		Reports	4,42
Waste	(S5) Cost of raw materials sent to landfill factored in waste management handling fees	Landfill diversion	1,66
	(S6) Establish networks so that waste can be reused and recycled	Waste market	3,87
	(S7) Sorting out legal aspects of waste handling by companies	Waste management compliance	1,10
	(S8) Identification, characterisation, and selection of potentially valuable material/waste fractions for future use	Waste characterisation	2,21
		Waste recovery project	19,34
	(S9) Extended producer responsibility	Extended producer responsibility	1,10
	(S10) Expand the focus on product recall: refurbishment, reconditioning, remanufacturing	Remanufacturing project	3,31
Resource	(S11) Encourage innovation in technologies that allow IS value chains	Technological innovation	7,73

Pathway (Arena)	Strategies (Agenda)	Experiments	% Total
	(S12) Training, innovation, and development in the management of new resources	Innovation project	6,63
		Research project	4,42
		Training	7,73
	(S13) Incorporate eco-design principles to ensure recirculation of products	Eco-design project	3,87

This strategy suggestion could imply that IS is undeveloped in practical applicability despite its theoretical importance. However, incentives of this type have been proven to have a beneficial effect in simulation studies, although its relevance depends entirely on the environmental and political conditions in which IS networks develop (Fraccascia et al., 2017).

Experiments focused on **(S8)** *"Identification, characterisation, and selection of potentially valuable material/waste fractions for future use waste recovery projects*" are the most frequently carried out at this stage of the transition (21,55%). Most experiments in this strategy aim to eliminate waste and, thus, promote a waste-to-resource exchange such as **waste characterisation and waste recovery projects**. For instance, there are activities centred around downstream solutions concerning the textile sector, such as recycling hospitality fabrics, household clothes, bus cloth, or sheep wool. The stakeholders participating in this solution have not created a new supply chain but used the municipal waste management collection to recycle the fabrics. Plastic waste is recovered from the ocean, coffee cups, and industrial waste to be converted as yarn for the fashion industry. Whereas some solutions are based on composting or energy recovery, others focus on adding value to waste, such as organic dyes from nuts used in garments or keratin recovery from slaughterhouses sold in the pharmaceutical sector.

Based on the findings, most of the solutions are closely related to a downstream solution rather than an upstream one; this might be explained because most of the initiatives somehow involve the public administration. In

this case, the public administration has to meet some targets set by the European Commission in their CE action plan (European Commission, 2020a). So, the public administration is funding more recycling targets to stimulate the collaboration between different stakeholders and meet the goals of a "zero waste to landfill" policy embedded as a primary goal.

On the other hand, the experiments in the strategy **(S3) "***Establish alliances between different agents to increase synergies*" are shown as the strategy with the second most reported experiments (19,34%). This experiment reflects a greater willingness to collaborate with other stakeholders, whether from the public or the private sector, in the form of **partnerships or pilot project agreements**. At this transition stage, the public administration seems to be deeply concerned with engaging different stakeholders through meetings, business fairs, and **workshops** to stimulate collaboration networks and have a voice in drafting public policies.

It was observed that companies manage most projects with the support of the public administration to create spinoffs such as new products out of coffee pods. Spinoffs result from advising companies to use the waste from coffee and plastic as a resource for new products. Few projects have turned into successful new business opportunities. They include secondary materials into their value chain, thereby changing or adding suppliers to their supply chain but exhibiting the potential to be scaled up. These projects have evolved into more robust partnerships but are often delivered as projects rather than a change in a business model.

In third place in terms of frequency (18.78%) by type of experiments is strategy **S12,** "*Training, innovation, and development in the management of new resources*" this strategy is characterised by **research**, development and **innovation** projects and **training** of highly qualified personnel. The findings offer insight into companies' actions and strategic considerations that have realised waste-to-resource innovations. These findings may be utilised to operationalise business strategies and government policies (Velenturf, 2016b).

Laboratory experiments or pilot phases in wood, plastics, textiles, bio-organics, and paper sectors are identified. It could be said that the projects have arisen more from an exploratory phase than from a critical commitment to changing the companies' strategy. This exploratory phase of projects has received some public funding or spontaneously arisen among companies to verify their technical feasibility. This funding comes from **grants** and is mostly funnelled to pilot projects.

It may seem that the release of the CE action plan by the European Commission has resulted in money flowing to these experiences, with different targets in projects and more focused on deepening IS activities across various sectors before scaling up some solutions. Moreover, the results of this study suggest that innovative exploratory capabilities only positively impact firms' responses to different stakeholder pressures, with the public sector being the driver of these initiatives (Jakhar et al., 2019).

Another strategy widely taken into action by stakeholders has been the **S4** "*precise diagnosis of existing waste, resources, and consumption associated with the different industrial sectors strategy*" (10.50%). This strategy presents experiments such as **reports** showing the latest trends in the field and methodologies to discover new business opportunities by assessing capabilities, essential resources, and strategies via digital platforms, toolkits, or methods.

Most of these **methodologies** are designed to be applied to any industry. Most of these methodologies aim to make some diagnosis or offer some tool to measure the status of companies about the potential to engage in symbiotic activities. A similar approach to such experiments has been used in the Humber region (UK), where methodologies and tools were produced to address some impediments to IS. The methods emphasise preliminary assessments of local conditions and stakeholder requirements, involvement of essential stakeholders, identification of IS possibilities and their evaluation to establish feasibility and thus assist implementation (Cervo et al., 2020). Authors such as Yuan et al. (2019) have also developed a methodology for assessing the effect of policy on the implementation of IS systems from the firm's perspective.

However, as shown in the literature review section, there is not a robust body of literature showing how diverse the experiments are, promoted, or influenced by different stakeholders. This thesis aims to do that, and based on the experiments deployed by the stakeholders; it relates how stakeholders collaborate with other stakeholder groups to carry out the experiments.

Table 21 shows the number of times (expressed as a percentage) specific stakeholders **collaborate** with other stakeholders to **promote** transition-related experiments. Each time an experiment is promoted by one of the stakeholders, it is determined whether this has been done without collaboration or in collaboration with other stakeholders, showing the frequency (%) in which stakeholders collaborate to carry out the experiments.

Table 21. Stakeholders' collaboration

	Business	Business Association	Foundation	Local and regional administration and agencies	Research Institution	Social Organisation	No Collaboration
Business	36%	8%	3%	3%	6%	1%	43%
Business Association	94%	0%	0%	0%	0%	0%	6%
Foundation	70%	0%	0%	0%	0%	0%	30%
Local and regional administration and agencies	48%	3%	4%	16%	9%	3%	17%
Research Institution	60%	10%	0%	0%	10%	0%	20%
Social Organisation	25%	0%	0%	0%	50%	0%	25%

When values of 0% are observed, there is no experiment promoted by a specific stakeholder that has been done in collaboration with any other stakeholder. Likewise, low percentages refer to a low degree of collaboration in executing experiments. On the contrary, high percentages show a concentration of collaboration between specific experiments.

Consequently, the stakeholder "business" is the one that carries out the most experiments without any external collaboration, which would indicate that these experiments are carried out in isolation or perhaps in an intra-organisational fashion. However, as shown in Table 21, "**foundations**" and "**business associations**" are the stakeholders that collaborate the most with **businesses**.

The role of this stakeholder could also be referred to as the transition manager (Loorbach & Rotmans, 2010). This role allows them to participate in IS activities and act as an intermediary between the different actors, as it has less commercial and more social characteristics. Transition managers handle the information society transition process (learning and communication), bring new knowledge, and find innovative solutions (Cramer, 2020a). Consequently, a collaboration between the waste exchange experiments has primarily occurred through participation between the businesses mediated by this stakeholder.

On the other hand, other stakeholders, such as local and regional administrations representing the public sector, have proven to be more even-handed in collaborating with different stakeholders. Through its participation in other experiments, the public sector has demonstrated its leadership and entrepreneurial effort in collaborating with other stakeholders in experiments such as pilot and research grants, scholarships, courses, workshops, diagnostics, partnerships, and public procurement. The role played by this stakeholder in the experiments is somewhat different from simply being the funder of specific alternatives, which leads one to think that the critical contribution of this actor is to serve as an institutional entrepreneur using techno-economic and socio-political support networks as a strategy (Jolly & Raven, 2015).

4.6 Transition monitoring

This section describes the phase called transition monitoring. This part of the transition reflects the previous steps based on evaluating the previous results. The best way to assess the results is by evaluating the experiments, as they are a sample of the steps followed sequentially in the TM framework.

During the experiment phase, stakeholders were consulted on evaluating these experiments. However, no experiments have been effectively measured because there is no framework established to track progress on such matters.

4.6.1 Indicators

Instead, stakeholder groups (Appendix D) have suggested indicators to assess the experiments at a future stage (Table 22). Many of the indicators proposed by stakeholders relate to indicators developed by public agencies to measure the effectiveness of implementation activities (e.g. the EC, the Chinese government, the Spanish Ministry for Ecological Transition and so on). So, it was found that the indicators and their calculation released by government bodies may serve to also assess the experiments in the transition. This suitability is because these indicators track progress on IS actions when a systematic approach is considered, outweighing other indicators reported in the literature regarding coverage.

Table 22. Indicators suggested by stakeholders

Stakeholder	Indicators
Business	Waste generation (kg)
	Secondary material (%)
	Energy efficiency
	Waste recovered (%)
	# Environmental certifications
	CO2 emissions
	# Eco-designed products
Business association	Secondary material (%)
	Waste generation (kg)
Foundation	Material, energy & water flow
Local administration	# Procurement bidding documents
	Waste generation (kg)
Research institution	Courses (#)

According to Pojasek (2009), this type of indicator can be used to plan and monitor the effectiveness of proposed actions and provide guidance, thereby allowing the possibility of making adjustments and improving the solution, which is the exact aim of the transition. Some studies have pointed out that using leading indicators for performance measurements is advisable, as they provide warnings about future performance (Kravchenko et al., 2019; Morioka et al., 2016). The indicators of this sort were created nationwide, so an adaptation to assess experiments is required.

Hence, some key aspects (e.g. the calculation) needed to be refined, as detailed in Table 23. For example, indicators such as waste generation asked for companies' revenues instead of GDP. The recycling rate was calculated based on specific waste streams (plastic, paper, and paperboard waste) and not only constrained to packaging waste. The circular material use rate indicator, whose aim is to demonstrate the implementation of a circular system, gathered secondary material consumption statistics in companies following the categories described by the EC (European Union, 1994).

Table 23. Indicators developed, and their calculation

Refined indicators	**Calculation**
Self-sufficiency for raw materials (%)	*1-(net) import reliance*
Percentage of procurement	*[procurement (€)/total procurement (€)] x 100*
Generation of waste per € (kg/€)	*[generation of waste/revenues]*
Percentage of generation of waste per material consumption	*[generation of waste (kg)/materials consumption (kg)] x 100*
Energy productivity (kWh/€)	*energy consumption (kWh)/revenues (€)*
Percentage of green energy consumption	*[green energy consumption (kWh)/total energy consumption (kWh)] x 100*
Water consumption productivity (m^3/€)	*water consumption (m^3)/revenues (€)*

Refined indicators	Calculation
Percentage of the recycling rate of all waste	*[waste recycled (kg)/generation of waste (kg)] x 100*
Percentage of the recycling rate of plastic waste	*[plastic waste recycled (kg)/generation of waste (kg)] x 100*
Percentage of the recycling rate of paper and paperboard	*[paper and paperboard waste recycled (kg)/generation of waste (kg)] x 100*
Percentage of circular material use (CMU) rate	*[secondary materials (kg)/material consumption (kg)] x 100*
Percentage of investment	*[investment on tangible goods (€)/total investment on real goods (€)] x 100*
Percentage of jobs	*[jobs/total jobs] x 100*
Percentage of patents	*[patents/total patents] x 100*

Whereas the still-under-development food waste indicator was eliminated, green public procurement, also under development (European Commission, 2018), was created exclusively for this study. The proposal for this new indicator rests because it may cover most industrial activities at the micro level rather than a single industry sector (i.e., the food industry). This new indicator was rebranded as 'Procurement', following the guidelines on the criteria that apply to this sort of procurement (European Commission & ARCTIC SPRL-Environmental Communications, 2017).

However, three new indicators were added to link IS and other critical variables entirely. Those indicators are energy productivity, water consumption productivity and green energy consumption, which were based on the guidelines provided by the Ministry of Ecological Transition (MITECO, 2018). These indicators were added as they are intended to measure productivity and eco-efficiency in natural-source inputs. Thus, when pieced together, they comprise nearly all the critical variables associated with a CE (Linder et al., 2017).

The set of indicators proposed in this study comprises 14 indicators (Table 23). It is highly oriented to IS practices regarding recycling, reuse, flow circularity information, investment, and natural resource inputs. To assess the IS actions with the proposed indicators, a 21-questionnaire survey (Appendix D) was administered to companies to determine the indicators' applicability if implemented. Subsequently, the above information was consolidated to understand the indicators' relevance.

A total of 17 stakeholders participated in the survey. Seventeen per cent of the surveyed stakeholders identified their industrial activity as taking place in the mechanical and electrical engineering sector. In contrast, 36% of the stakeholders identified themselves as working in construction, production of primary metals or recycling, remanufacturing and reusing. This result indicates that half the stakeholders surveyed have the potential to generate some waste that serves as a resource to another company.

The questionnaire information shows that some indicators, such as self-sufficiency for raw materials, did not provide valuable data. The list of critical raw material data companies was asked to gather to complete the indicators was the same as the list released by the EC (European Commission, 2018). The lack of data reported by companies might be because "companies in the area do not trade with this sort of material", which is mainly rare earth metals imported from outside the European Union, according to some respondents when asked on the matter, and it is beyond the scope of this study.

In Figure 12, low procurement is expressed in the low rate of purchases with criteria for eco-design, eco-labelling, biodegradable and recyclable packaging, remanufacturing, reuse or prevention and reduction of waste (9.4%). As can be seen, the companies are not taking advantage of symbiosis opportunities, and perhaps the necessary measures have not been brought to reach this point, despite having benefits in their production processes (Prieto-Sandoval, Jaca, et al., 2018).

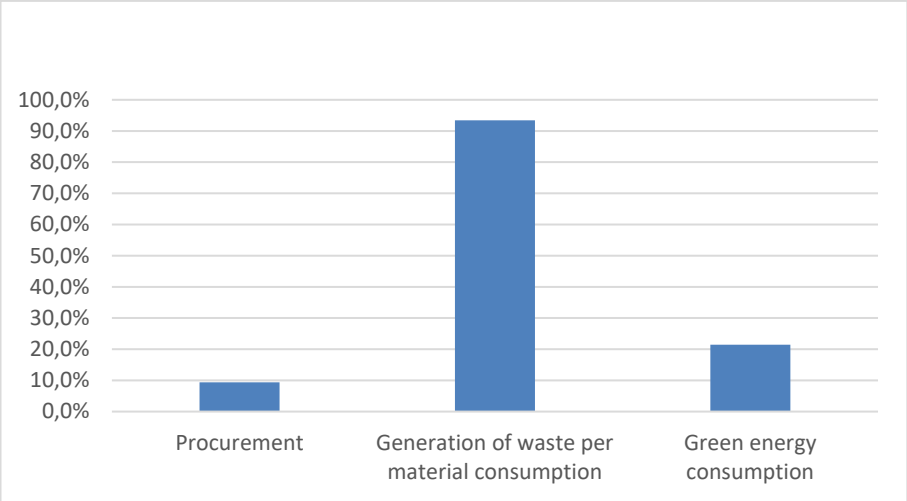


Figure 12. Material and energy indicators

Also, the companies in the sample generate 0.35 kg (Table 24) of waste per euro invoiced, with the recycling, remanufacturing and reuse companies having more weight in this indicator. This result might be related to the quantity and the quality of the input they receive as raw material to be processed. The result might imply more significant losses in the process, which are inherent to the business they operate. The quality of the input may be lower than a virgin material of similar characteristics. Though this indicator is simple, transparent and easy to measure, authors such as Iacovidou et al. (2017) propose selecting metrics suited to assess resource recovery from waste to optimise the multi-dimensional value of waste recovered.

Table 24. Results from indicators in other areas

Indicators	Result
Generation of waste per € (kg/€)	0.35
Energy productivity (kWh/€)	2.26
Water consumption productivity (m3/€)	0.002
Percentage of CMU rate (%)	39.3

The percentage of waste generated by materials consumed is 93.4%, an apparent operational inefficiency. Nevertheless, this is partially explained in companies wherein overall waste records are kept in their monitoring and control documents, including the waste generated through handling their suppliers' waste and not used as raw material (plastic packaging and paperboard).

This result would indicate an excess of waste that is not generated voluntarily. This situation could be improved through alliances with other companies that could receive excess waste as materials in their processes or receive prior treatment and then be offered as by-products, as suggested by aid et al. (2017). Although there are materials that can be declared as by-products for commercialisation, others may need additional handling or treatment before being converted into 'food' for other companies.

Regarding the indicator of energy productivity (Table 24), the most significant contribution is in industries related to construction, chemical industries, and the production of primary metals. This sector is characterised by high energy demand and high processing of virgin material, which notably increases energy consumption and, therefore, the indicator. This situation could be balanced by increasing the consumption of green energy since, according to the surveys, only 21.4% consume green energy from the total energy matrix used in their production process.

The water consumption productivity indicator corresponds to the efficiency of this resource, yielding a consumption of 0.002 m^3 of water for each euro invoiced. In general, no company or industrial sector contributed much to the calculation of this indicator. Although there are companies with low water consumption, high consumption of this resource is more related to the food industry, a sector not represented in this study.

The incorporation of energy and water indicators proved helpful in the set of indicators proposed for this thesis. The appropriateness of these indicators showed a focus heavily based on a material dimension. Llorente-González and

Vence (2019) found that leaving these indicators aside will not reflect a comprehensive and systemic character of a transition.

This thesis identified two materials that may be subject to this commercialisation or a reduction (Figure 13). These are cardboard/paper materials and plastics, whose consumption generation rates were 6% and 3.6%, respectively. The percentage of waste generated for these materials can be considered low. However, the benefits of making the transition should be highlighted since the waste of these common materials would cease to exist. Instead, it would be exploited in a company or as input for other organisations. In particular, the waste streams quantified for this study could shed some light on the importance of enacting the basis for a resource recovery to decouple industrial output from primary resource consumption (Gregson et al., 2015), as these streams were quantified in the survey. It could be helpful to search for the most common raw material that is also of great economic importance to companies vulnerable to supply disruption in a regional area to measure the benefits of different waste valorisation options (Corona et al., 2019).

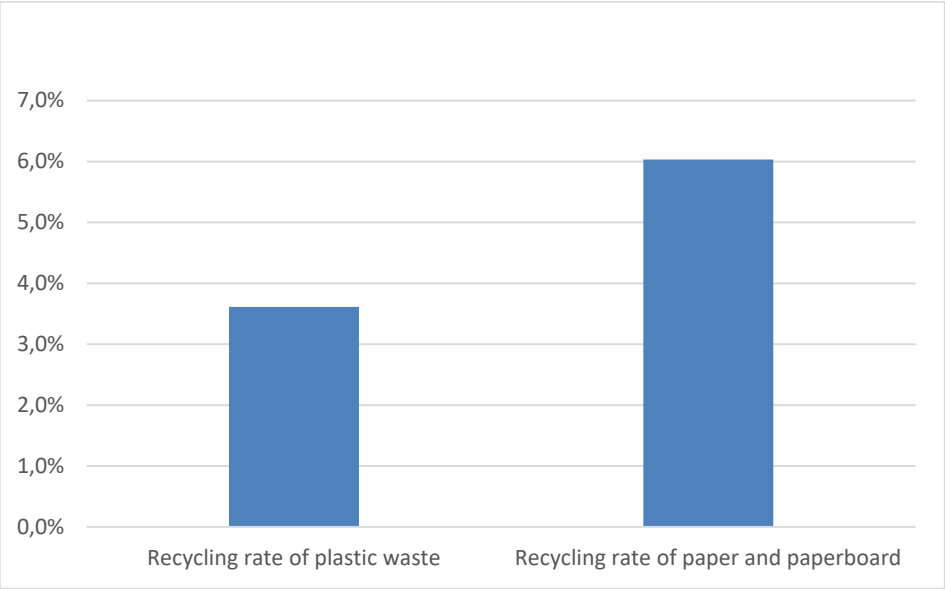


Figure 13. Indicators related to waste management

The rate of CMU (Table 24) is high compared to the other indicators, which indicates that companies are using secondary material as part of their production processes and replacing part of the virgin material consumed with material that has been reintroduced to the system. Although investments have been appreciably low, the necessary measures have been taken in manufacturing. Perhaps an increase in the indicators of purchase and investment would increase the CMU indicator, contributing to the closing of the loops of materials, energies and natural resources (Corona et al., 2019)

The companies allocate scant resources to acquire goods and supplies related to the IS. For example, only 20.7% of companies have purchased technologies for wastewater treatment, waste, or technologies with a potential or indirect contribution to mitigating greenhouse gas emissions compared to the total investments made in 2017. Additionally, the companies reported that around 24.1% of the workforce performs some IS-related activity. Indeed, this small amount of human capital dedicated to IS direct impacts the little innovation and development of products and services, which is crucial in transitioning to this new model (Ormazabal et al., 2018). Because of this, the percentage of patents might be low (11.4%), as shown in Figure 14.

Companies have not taken full advantage of all the opportunities in an IS. Perhaps the necessary measures have not been executed yet, despite having benefits in their production processes (see CMU indicator). In addition, much of this commitment is not fully manifested in trends toward circular business models, as seen in the low investment in human capital Figure 14. So, companies are prevented from obtaining benefits through symbiosis programs with other companies willing to use by-products or secondary materials in their production processes.

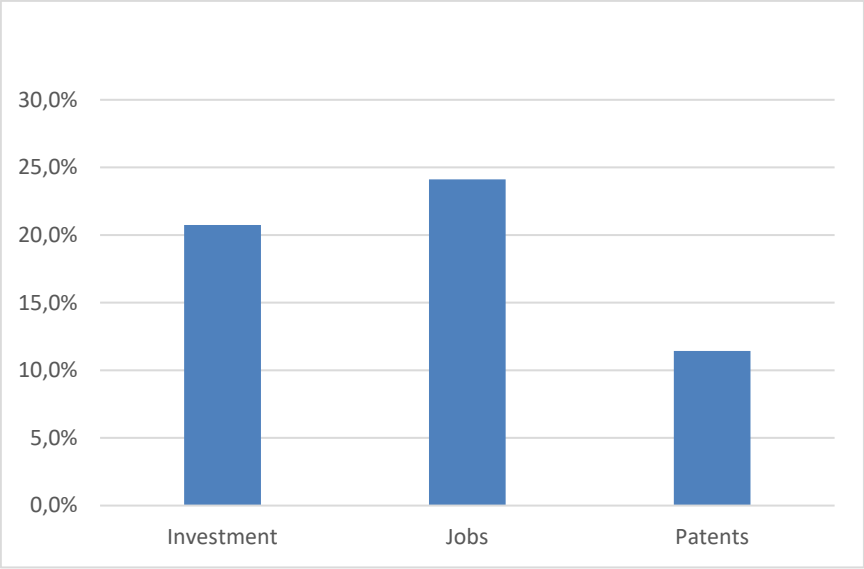


Figure 14. Investment, jobs, and patents indicators

Furthermore, increased purchase and investment budgets in this sort of action could help close the loops in materials, energies and natural resources through innovation and development programs (Smol et al., 2017). These indicators might be able to represent the systemic nature of the transition. However, they lack robust measurement of added economic value built on current sustainability assessment frameworks such as life cycle assessment (Corona et al., 2019).

5

Transition Management methodological framework: Main features

The results presented here show the sequence that end users of the framework should take to achieve such a transition.

5.1 System boundary

Cooperation between the supplier and the client and between the manufacturer and the consumer is necessary (Rashid et al., 2013). This network of businesses, which includes local/regional public authorities such as municipalities, should collaborate on material and energy consumption (Korhonen et al., 2018). In other terms, material and energy flows cross organisational, administrative, and geographical barriers.

Physical flows inside the limits of a geographical system necessitate inter-organisational management. Such inter-organisational arrangements in an IS are pivotal to systematically controlling and managing physical flows. Any occasion to create multiple opportunities across value chains to foster IS networks (Domenech et al., 2019) will likely occur due to industrial activities and geographical proximity among different companies within a defined area (Chertow & Ehrenfeld, 2012; Ghisellini et al., 2016).

Consequently, the system boundary of an IS is relevant to determine the geographical scale at which material exchanges and recycling of various forms of waste occur (Chertow & Ehrenfeld, 2012; Ghisellini et al., 2016). Therefore, several systems that produce and manage industrial waste were studied to understand how and who could be responsible for leading the transition within the system boundary.

Firstly, some theoretical networks were simulated in an industrial park to detect possible waste-to-resource exchange. These potential matches give us an idea of what kind of resources could generate symbiosis between companies to open up opportunities for creating new roles in resource management (Neves, Godina, Azevedo, et al., 2019). For instance, some exchanges would have limited information on resources that have left their organisations' boundaries but are still likely to remain in the system, as indicated by the results.

In addition, waste from industry could be further generated and managed outside the geographical boundaries of the industrial park. Specifically, the following sectors that could be involved and aggregated in this way would be in industrial clusters. The clusters are known for the involvement of different

stakeholders that plays a crucial role in creating cooperation and communication among companies and other stakeholders because of their highly industrialised output and the greater awareness of such opportunities (Ormazabal et al., 2016; Rincón-Moreno et al., 2021).

Moreover, data on industrial waste streams were collected. This finding could be used to more accurately observe how waste management can create synergies boosted by the geographical proximity of the industrial parks and clusters (Freitas & Magrini, 2017). This value creation might help integrate industrial waste management into resource management to transition to new models based on IS (Aid et al., 2017).

These organisations are increasingly interested in creating inter-organisational resource networks to build long-term partnerships and take advantage of available knowledge resources such as regional material flows (Aid et al., 2017). Altogether, the sectors studied to start deploying the framework belong to a region that might be categorised as part of the meso-level. The meso-level comprises regimes defined by commonly associated rules in a community (e.g., problem agendas, search heuristics, guiding principles) and contribute to the community's stability (Geels & Schot, 2010) could create a network to govern the symbiosis.

Within this system boundary, the inter-organisational management and the strategies to develop the TM framework are given. For this reason, this thesis has concluded that the system boundary definition should be limited at the meso-level, which includes industrial parks, industrial clusters, and industrial waste management (Figure 15).

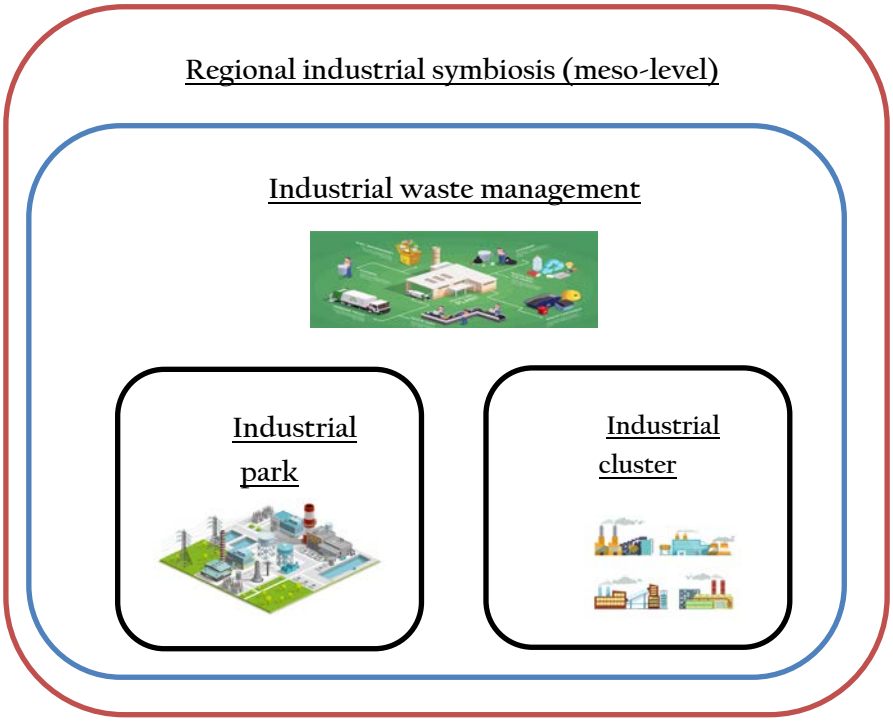


Figure 15. System boundary for the TM framework

5.2 Transition arena

The first part of the TM framework focuses on finding those stakeholders with whom the transition can be developed. They are expected to be leaders or frontrunners, to have projects or at least to be connected to IS issues. This thesis evidences that implementing IS from a group-level approach requires the inclusion of various perspectives. Collaboration is the key to the transition, especially when exchanging resources is necessary for symbiotic opportunities to ensure such a transition. The transition would not be possible without stakeholder involvement through a solution-focused collaboration between them to reduce the extraction of raw materials in the long term (Millar et al., 2019; Velenturf & Jopson, 2019).

To make it viable, these perspectives should come from all stakeholders involved, such as policymakers, governmental bodies, manufacturing industries, business associations, social organisations, research institutions, foundations, and so on (Ghinoi et al., 2020). This thesis has found that to achieve the transition, six groups of stakeholders might be needed to reach compromises that will enable them to facilitate the transition.

The particular role of multiple stakeholders in the transition help support a network value (Ghinoi et al., 2020). In this first part of the four-cycle transition process (Figure 16), the public administration led the stakeholders via a top-down approach by facilitating synergies or the creation of synergies is not materialised so far between different stakeholders. Moreover, the government has established a strategic vision aligned with the European Commission's CE action plan (European Commission, 2020b).

Public administration, social organisations, social organisations, or foundations might provide this role of a manager in the transition to governing the process (learning and communication) and its substance (offering new knowledge and finding ambitious solutions). This role is in charge of building synergies initiatives at an early stage. Transition managers might obtain the assistance of other stakeholders to help synergies get started. They are concentrated onindustry frontrunners (specialist actors) but also work with other stakeholders who were willing to participate in this transition.

As a transition manager, information is collected, circular enterprises are developed, and good preconditions are produced in collaboration with various partners. This type of stakeholder might be involved in different projects without a clear trade-off. Third-party stakeholders that serve as managers could be crucial for these transitions. Therefore, integrating more stakeholders that fulfil the role of managers but with a less commercial profile and a more social nature that engages more stakeholders and offers trust and long-lasting relationships could be the key to the process. This type of stakeholder is also reported in the literature as one that approaches other stakeholders, notably local government and businesses (Cramer, 2020a), as part of a system (Ng & To, 2020).

Figure 16. Transition arena analysis

Additionally, based on the stakeholders' responses about the expected points for developing the transition, various dynamic patterns that interact in multiple ways were explored to generate diverse paths. These perspectives of transition pathways have emerged, resulting in typologies that differ in terms of the features they stress. These have been gathered into three pathways that would facilitate the transition. These pathways are organisational, waste and resources. The three pathways broadly represent the challenges of transitioning toward an IS (Domenech et al., 2019; Saavedra et al., 2018) and facilitate forming stakeholder partnerships.

Although these pathways have already been mentioned in the literature (Mortensen & Kørnøv, 2019; Schlüter et al., 2020), the selection of these pathways represent the different direction stakeholders should take to realign objectives and facilitate the transition (Geels & Schot, 2010). The organisational pathway would help to realign solutions to establish synergies based on the social dynamics of the different actors. Generating strategies and experiments through this pathway could potentially promote agreements and develop lasting relationships in the transition process.

The waste pathway would help to strategise and experiment with integrated solutions to recover the value of waste. This pathway aims to reorient waste management by focusing on the quality of recovered materials to increase opportunities for synergy creation. Finally, the resource pathway points to the reorientation in creating strategies and experiments to synchronise stakeholders in resource management. This reorientation is done to consolidate partnerships allowing secondary materials to be incorporated from waste recovery processes. These conditions may create inter-organisational resource networks to build long-term partnerships and take advantage of available knowledge resources such as regional material flows (Aid et al., 2017).

5.3 Transition agenda

One of the findings of this thesis indicates that a suitable way to achieve the transition is through three types of pathways: organisational, waste and resource, which could facilitate the transition supported by the stakeholders. The stakeholders are aware of their relevance in promoting this paradigm change. Then, building consensus with the stakeholders about the different IS strategies that should be implemented for transitioning on such pathways are pivotal. The stakeholders provided a broad range of strategies that might improve the transition if prioritised.

The consideration of these strategies by the stakeholders shows that even though they come from different backgrounds and each one of them represents a unique interest, they highlight how implementing these strategies may assist in

joining forces and creating economic value by collaborating with other stakeholders (Kortmann & Piller, 2016). Participants also believe that collaboration through networks and alliances between different stakeholders would help to create value from waste.

The strategies that need to be deployed require different system parts, such as stakeholders, to develop an IS network. The strategies suggest exploring how an inter-organisational perspective could foster collaboration to develop a CE, including a plurality of stakeholders' views. The fourteen most relevant strategies revealed some common characteristics in incentives, collaboration, characterisation, recirculation, and R&D and innovation that could be used to implement IS practices influencing business network opportunities (Figure 17).

So, a transition agenda must be developed through strategies that could go from narrative to practice without neglecting other strategies but rather selecting those from both the bottom-up and top-down approaches (Jurgilevich et al., 2016). The stakeholders' IS strategies consider that the public administration must strongly support the conditions for using wasted resources. This type of support is called for in those strategies that seek to establish tax incentives or penalise the waste of resources sent to landfills.

Similarly, the participants have estimated that improving research and development capabilities in resource characterisation will allow the materials to be recycled in an IS. The participants' perception is reflected in the strategies that seek to implement development and innovation in products and technologies that facilitate the incorporation of these materials in the value chain, either through public procurement or collaboration networks with other companies. This perception is observed across the three pathways studied.

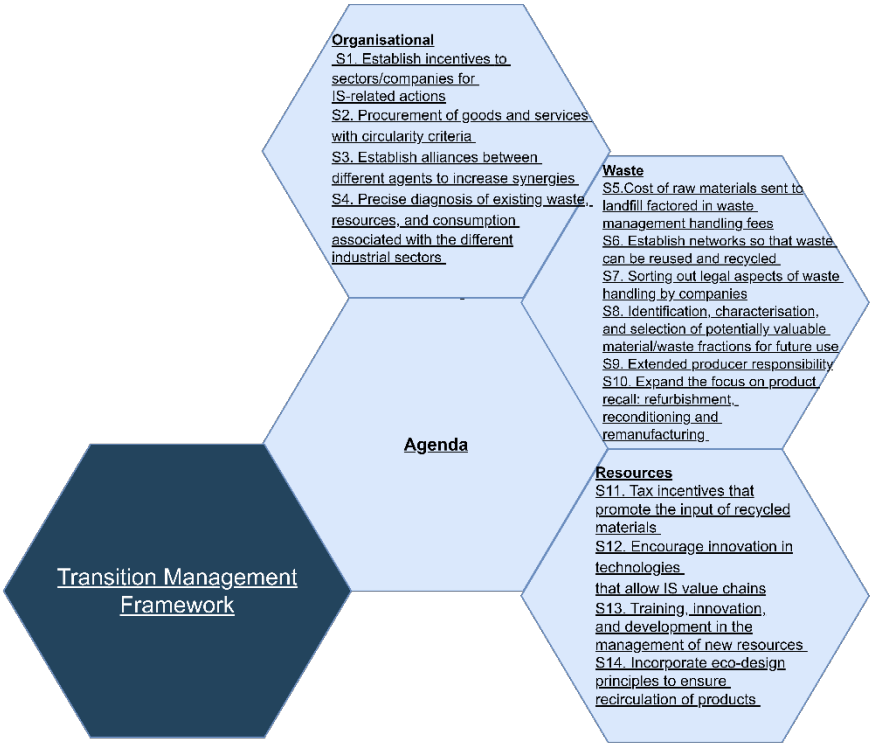


Figure 17. Transition Agenda analysis

5.4 Transition experiment

This phase show 20 experiments that have been carried out by the different stakeholders involved. From this phase, it can be highlighted (Figure 18) that the most relevant experiments for the transition are those that valorise waste (characterisation and recovery), establish collaboration networks (partnerships, pilot projects and workshops), and offer diagnostic tools (reports and methodologies). Waste management enforced through a regulatory scheme towards reducing waste is also crucial to harnessing resource efficiency opportunities. Furthermore, there is a focus on creating new value through R&D activities to improve the management of resources (R&D projects and training).

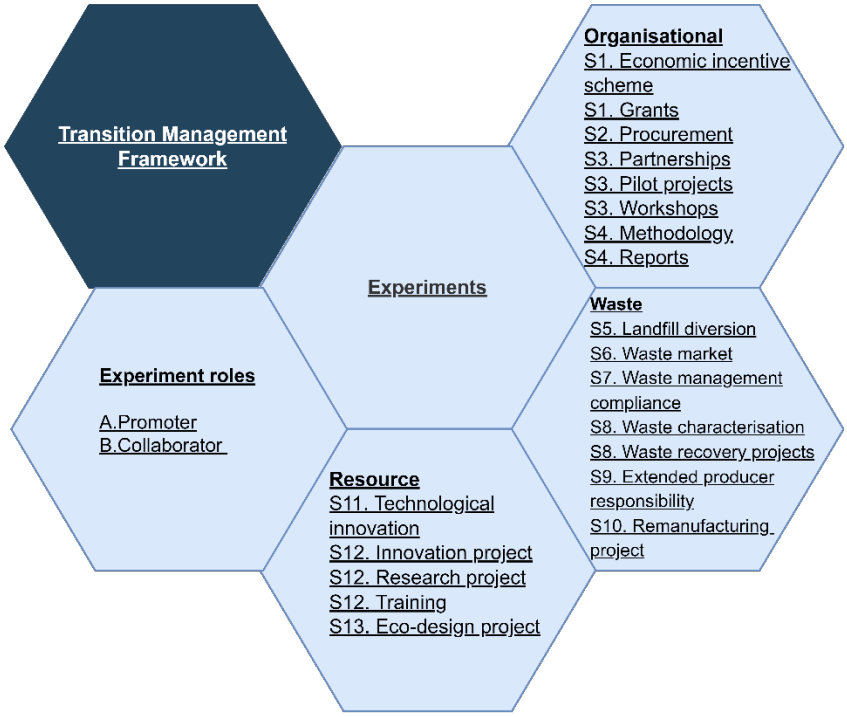


Figure 18. Transition experiment analysis

Additionally, the execution of these experiments has counted to some extent with the direct collaboration of the six stakeholder groups determined for this thesis. It has been observed that two types of roles are defined among the stakeholder groups during this phase: promoter and collaborator. Although based on the empirical observation in this thesis, such collaboration is not necessary to carry out these experiments, the literature on collaborations is extensive on the need to involve the various stakeholder groups to ensure stakeholder engagement over time (Goodman et al., 2017; J. Park et al., 2018; Patricio et al., 2018; Turken & Geda, 2020).

For example, a transition must be executed between several stakeholder groups like the ones presented in this thesis to be facilitated and achieve its objective. Thus, it is suggested that the distribution of the roles of collaborator and promoter among the six stakeholder groups across the different transition groups is advisable, although at a higher percentage of collaboration than the one

observed in this thesis. While concentrating on a high percentage, the collaboration with a particular stakeholder does not in itself show any disadvantage; this could lead to drawbacks. Ensuring its success over time depends mainly on constant collaboration and networking to overcome bottlenecks.

5.5 Transition monitoring

Developing indicators is pivotal for data-driven decisions to be made and tracked. This data-driven approach will help to weigh the holistic benefits of IS strategies and may serve as a baseline to analyse the likelihood of a transition. Based on the information initially provided by the stakeholders, a series of indicators were created to reflect the possible evaluation of the transition activities. The indicators proposed in this thesis are cross-sector metrics based on this framework that will enable the stakeholders to measure IS-related activities.

These indicators were then tested in the region to see if they could be used in a transition context. Fourteen indicators can be used to track the transition and to check the potential to create symbiosis (Figure 19). The indicators proposed in the TM framework primarily measure the potential for creating synergies, such as indicators 1, 3, 4, 8, 9, 10 and 11. They measure the potential to recover waste and be reincorporated into the value chain. Therefore, these indicators would be helpful in the waste and resource transition pathway.

Other indicators such as 2, 12, 13 and 14 are related to more organisational aspects, so that they would be of good use in this transition pathway. The remaining indicators (5, 6 and 7) are transversal to any activity as they would measure the environmental impact of the different actions in the transition. Although these indicators measure the more material aspects of the transition in terms of a given action implemented, they do not directly measure the collaboration between the different stakeholders. However, the percentage of collaboration in the transition experiments would determine whether the transition is going in the right direction.

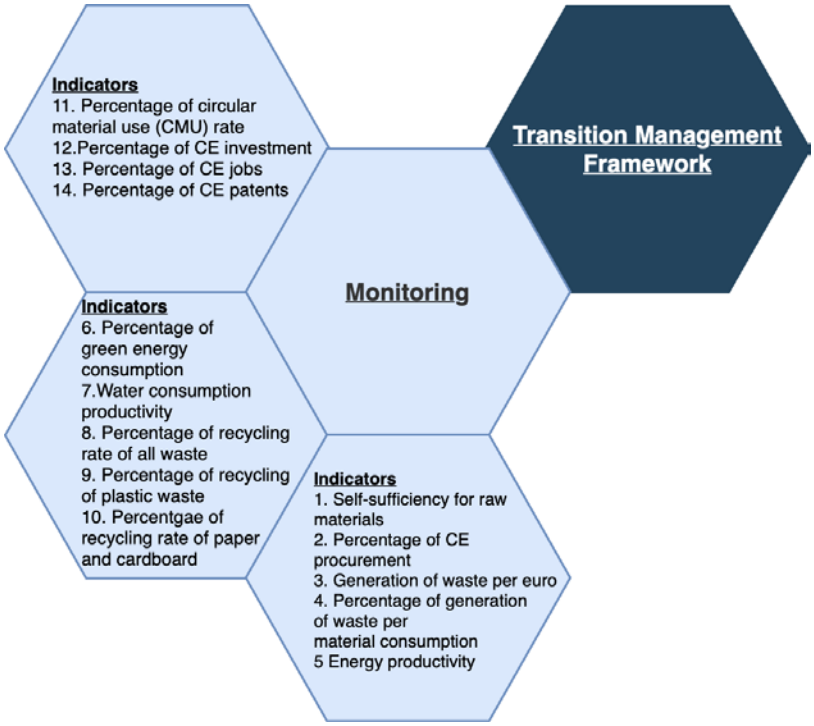


Figure 19. Transition monitoring analysis

5.6 TM methodological framework

The system boundary must be the first step towards a transition. The system boundary defined in this thesis suggests that managing resources and waste is pivotal to sustainably addressing society's future demands through inter-organisational waste-to-resource networks (Herczeg et al., 2018), as stated by the principles of IS (Cobo et al., 2018). The opportunities offered by an iterative process, such as the TM framework, would lead to a more solid foundation within this boundary to ensure and accelerate the transition to a clean and efficient model. The TM framework exhibits four phases, as presented in the previous chapters (Table 25). After the system boundaries have been established, the Arena transition is carried out. In this phase, the objective is that under a common goal (transition to an IS towards a CE), the identified six **transition**

stakeholders allow for creating a virtual **transition network** in which the **transition pathways** could be set and further developed.

These transition pathways are the guidelines by which stakeholders should develop strategies and actions that operationalise the TM framework.

Similarly, the public administrations should take the first steps in the transition and bring together the different stakeholders to create the transition networks or IS networks. The role of the public administration is more similar to that of a **transition manager**, as it manages the relationship with stakeholders and establishes the game's rules for all the **transition stakeholders.**

Table 25. TM methodological framework

Arena		Agenda	Experiments	Monitoring
Stakeholders	Pathway	Strategies		Indicators
1. Local administration 2. Businesses 3. Business associations 4. Research institution 5. Social organisations (e.g. NGOs) 6. Foundation	Organisational	(S1) Establish incentives to sectors/companies for IS-related actions	Economic incentive scheme	Self-sufficiency for raw materials (%) Percentage of CE procurement Generation of waste per € (kg/€) Percentage of generation of waste per material consumption Energy productivity (kWh/€) Percentage of green energy consumption Water consumption productivity (m3/€) Percentage of the recycling rate of all waste Percentage of the recycling rate of plastic waste Percentage of the recycling rate of paper and paperboard Percentage of circular material use (CMU) rate Percentage of CE investment Percentage of CE jobs Percentage of CE patents
			Grants	
		(S2) Procurement of goods and services with circularity criteria	Procurement	
		(S3) Establish alliances between different agents to increase synergies	Partnerships	
			Pilot project	
			Workshops	
		(S4) Precise diagnosis of existing waste, resources, and consumption associated with the different industrial sectors.	Methodology	
			Reports	
	Waste	(S5) Cost of raw materials sent to landfill factored in waste management handling fees	Landfill diversion	
		(S6) Establish networks so that waste can be reused and recycled	Waste market	
		(S7) Sorting out legal aspects of waste handling by companies	Waste management compliance	
		(S8) Identification, characterisation, and selection of potentially valuable material/waste fractions for future use	Waste characterisation	
			Waste recovery project	
		(S9) Extended producer responsibility	Extended producer responsibility	
		(S10) Expand the focus on product recall: refurbishment, reconditioning, remanufacturing	Remanufacturing project	
	Resource	(S11) Tax incentives that promote the input of recycled materials	Tax incentives	
		(S12) Encourage innovation in technologies that allow IS value chains	Technological innovation	
		(S13) Training, innovation, and development in the management of new resources	Innovation project	
			Research project	
			Training	
		(S14) Incorporate eco-design principles to ensure recirculation of products	Eco-design project	

The following section, called the transition agenda, aims to get the stakeholders to strategise on the different pathways by which they believe the transition to an IS model can be facilitated. In these first two phases of the framework, it should be noted that governing the transition has a top-down approach. This approach means that managing the transition with the different stakeholders should focus on proactive management, such as developing inter-organisational networks, which could help advance the transition collaboratively.

In the subsequent two phases, the focus of the framework is more on the operationalisation of the framework. This focus means that the stakeholders aim to ensure that networks and pathways generate strategies to materialise actions that facilitate the transition and that this can then be measured. As this is the most active part of the framework where waste and resources are exchanged, the approach is more bottom-up oriented. This result indicates that the stakeholders who execute the synergies should guide the transition at this stage.

In addition to the role of the manager (local and regional administration), which in the two previous phases was more relevant, in this phase, although equally relevant, other stakeholders also actively participate in this role (foundation). In addition, two new roles are identified (**promoter and collaborator**) to carry out the multiple experiments that can be assigned to any stakeholder group interested in the transition. The promoters perform the initial execution of the experiments, and the collaborators accompany the promoters in this mission. However, the stakeholder business showed the highest percentage of experiments and collaborations. This high percentage can be explained by the fact that they control the physical resources to execute the synergies.

Finally, the final part of the framework is the monitoring phase. Here 14 indicators have been identified that could help measure the transition's progress. These indicators' essential characteristics are that they tend to count more waste and resource management business. Although one could argue for the inclusion or exclusion of these indicators, they allow an early stage to evaluate the experiments being carried out. It is expected that these findings might subsequently be extended to other locations, such as emerging countries, to

prevent regions from being entrenched in unsustainable management as industrial outputs increase.

6 Verification of TM framework: a case study in the Humber region

This section shows the results in the Humber region. The verification aims to improve the TM framework by understanding the dynamic of different contexts, such as the one in the Humber region, that might help frame the process conditions needed to transition towards an IS within a CE

6.1 Context of the Humber region

The Humber region is a vast, dynamic industrial area with various sectors ranging from the largest concentration of food processing companies in the UK to primary oil refining and chemical and biochemical manufacturing facilities. The following sections show the results obtained in the Humber region. The observations collected with the desktop research were complemented by the responses received in the interviews (Appendix E).

This process aims to verify the TM framework resulting from the Basque Country contrasted with the outcomes of the Humber region during and after the NISP. This process considered the stakeholders, pathways, strategies, experiments, and indicators that might facilitate a transition. The verification will contextualise the framework's main characteristics that will enable any region to move towards a transition.

6.2 System boundary

As seen in both regions studied with the TM framework, a key feature to implement has a strong industrial system. Having an established industrial ecosystem in place when the NISP programme started has been a positive factor after some initial obstacles. Nevertheless, industrial waste management has not been considered in the system boundaries in the Humber region. This is mainly because there were independent companies paid for by the public administration that managed synergies on behalf of the companies taking and giving waste and resources.

However, if there is to be no public funding to facilitate such exchanges, it would be crucial to include the waste management sector to participate within the system boundaries of this IS network. The necessity of including waste management is not only observed and proposed in this thesis but is also mentioned in the literature. The shift to a waste management model where the waste is recovered and becomes part of the IS to boost the CE has been deemed crucial (Aid et al., 2017; Iacovidou et al., 2017).

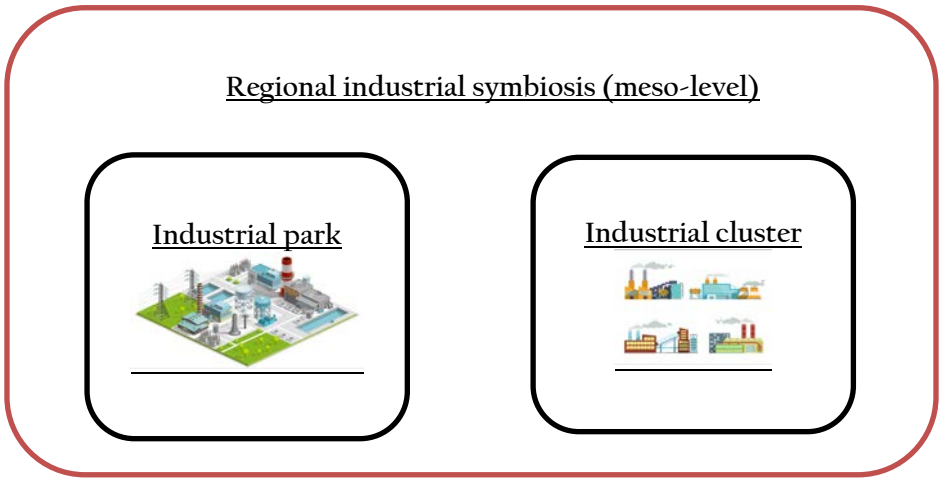


Figure 20 System boundary in the Humber region

Similarly, drawing the system's boundaries and applying the TM framework in regions with no solid industrial fabric might weaken the chances of implementing the TM framework. Furthermore, based on the two regions, rolling out the TM framework in the arena, agenda, experiments, and monitoring requires a continued focus on the meso level. Otherwise, the governance network working from the top-down and later from a bottom-up approach could not reach the IS because of a lack of crucial aspects, as described below (Table 26).

6.3 Transition arena

A top-down approach is crucial in both regions in the transition arena stage. The support of public administrations to initiate transitions through funding is one of the initial factors with which the transition should be initiated. The problem in the Humber region has been the modes of collaboration and experimentation since there was no formal transition process. It is worth noting that the IS in the Humber region started to enhance environmental performance. Unlike in the Basque country, the transition in the Humber region has been led by a narrow group of stakeholders, including businesses, business associations,

local administrations, and lastly, research institutions, but initially in a less prominent role.

Table 26. TM analysis in the Humber region

Arena		Agenda	Experiments	Monitoring
Stakeholders	Pathway	Strategies		Indicators
1. Local administration 2. Businesses 3. Business associations 4. Research institution 5. Social organisations (e.g. NGOs) 6. Foundation	Organisational	(S1) Establish incentives to sectors/companies for IS-related actions	Economic incentive scheme	Self-sufficiency for raw materials (%)
			Grants	Percentage of CE procurement
		(S2) Procurement of goods and services with circularity criteria	Procurement	Generation of waste per € (kg/€)
		(S3) Establish alliances between different agents to increase synergies	Partnerships	Percentage of generation of waste per material consumption
			Pilot project	Energy productivity (kWh/€)
			Workshops	Percentage of green energy consumption
		(S4) Precise diagnosis of existing waste, resources, and consumption associated with the different industrial sectors.	Methodology	Water consumption productivity (m3/€)
			Reports	Percentage of the recycling rate of all waste
		(S5) Cost of raw materials sent to landfill factored in waste management handling fees	Landfill diversion	Percentage of the recycling rate of plastic waste
		(S6) Establish networks so that waste can be reused and recycled	Waste market	Percentage of the recycling rate of paper and paperboard
		(S7) Sorting out legal aspects of waste handling by companies	Waste management compliance	Percentage of circular material use (CMU) rate
	Waste	(S8) Identification, characterisation, and selection of potentially valuable material/waste fractions for future use	Waste characterisation	Percentage of CE investment
			Waste recovery project	Percentage of CE jobs
		(S9) Extended producer responsibility	Extended producer responsibility	Percentage of CE patents
		(S10) Expand the focus on product recall: refurbishment, reconditioning, remanufacturing	Remanufacturing project	
		(S11) Tax incentives that promote the input of recycled materials	Tax incentives	
		(S12) Encourage innovation in technologies that allow IS value chains	Technological innovation	
	Resource	(S13) Training, innovation, and development in the management of new resources	Innovation project	
			Research project	
			Training	
		(S14) Incorporate eco-design principles to ensure recirculation of products	Eco-design project	

6.3.1 Stakeholders

The commitment of the stakeholders' network was initially low (Table 27). The stakeholder network tended to emphasise initiatives incompatible with the essential and valuable intention of engaging industries from various sectors in the program. In addition to limiting the opportunities for material networks, weak technological compatibilities within sectors were linked to organisational cultures with low degrees of experience with inter-firm collaboration, which has resulted in some reluctance to participate in the program in its origins (Mirata, 2004). This reluctance resulted in an initial fragmented industrial development and depicted a technical environment with limited opportunity for synergies to emerge within various sectors.

Table 27. IS in the Humber region in its origins (Mirata, 2004)

	Industry structure	Position of coordinating body	Project championship	Original institutional and framework	Awareness raising and commitment
Humber region	Difficult to integrate due to technicalities	No clear coordination	No industry-led frontrunners	Low level of cooperation	Fragmented

Nevertheless, the UK government-funded pilot initiatives, including in the Humber region. This funding financed private entities that initiated the facilitation of IS to help companies reduce costs and risk and open new business opportunities. They helped companies find partners who could use their waste as raw materials to grow synergies between companies (Abreu & Ceglia, 2018; Costa et al., 2010).

So, agreements presented and facilitated by a consultant and voluntary participation in the program with no fees charged but paid for by the government in services such as opportunity identification improved NISP's effectiveness (Jensen, 2016). The most prevalent coordination tasks were primarily assisting with informational and organisational concerns and obtaining multiple types of support for the programs, including financial support.

Facilitating such synergies between companies played a key role for as long as the funding has lasted. Since 2012, public organisations and local administrations developing IS in the Humber region have either lost public financing, notably NISP itself or have been dissolved or faced substantial funding cuts (Velenturf, A. 2016). The UK government withdrew from the NISP initiative, expecting it to be driven mainly by the private sector. It was thought that because NISP was so successful, companies would start paying for the service.

As a result, the feasibility of maintaining a collaborative culture based on these processes and the role public actors could play in IS projects outside entities like NISP became more of a hurdle. In the ten years since the programme stopped receiving public funding, businesses have generally not facilitated new symbioses between them.

Consequently, the funding cuts have diminished the Humber region's governance network. Moreover, a lack of solid policies on environmental regulation and climate change adaptation also weakened the governance capability to play an active part in the regional network. Currently, the regional governance system has a limited capacity to participate in planned collaborations and operationalise national government objectives and plans. Nowadays, local entities are trying to re-enforce IS through the CE strategy proposed for the region.

In this sense, the fact that the manager's role in the Humber region has been outsourced to consultants and not governed by the local administration has meant that stakeholders' participatory and collaborative nature during a transition has been lost. As observed in the Basque Country, transition managers can improve regional change processes, build alliances, help generate the required preconditions, and launch meaningful projects. They function as conduits between businesses and other necessary parties to help prepare, negotiate, and seal a circular contract and scale up and mainstream these activities (Cramer, 2020c).

The role of regional government in the Humber region in terms of planning and environmental licenses and luring investment appears to be underscored

(Velenturf, A. 2016). This increase in institutional capacity is an additional issue to financing IS initiatives, making them crucial actors through solid government policies that comply with the execution of value-creating IS and promote collaboration through intermediary stakeholders.

Likewise, there is a need to include another group of stakeholders collaborating in achieving the IS, such as the ones shown in Table 26. In that sense, stakeholders could help consolidate the transition and support the already established roles of companies and governments. Stakeholders who play a less economically driven role could serve as trusted third parties as coordinating functions must be maintained to achieve the required continuous increase in network performance. However, the commercial viability of the projects should be considered relevant. In both regions, industries will only move forward if they make business sense and are supported in their early stages by government intervention through incentives such as public procurement or subsidies.

To overcome this problem, following the lessons of the TM, the Humber region should be focused on a) improving connections between more stakeholders and b) establishing pathways with them. Incentives have played a significant role but IS has lagged without a facilitator to link top-down policy targets with bottom-up processes, as seen in the Basque Country.

A transition in any region must be refocused through a more participatory engagement with a broader number of stakeholders with whom the transition has been initiated, such as in the Basque Country (Table 25). Existing stakeholders in symbiotic relationships should secure funding through local enterprise partnerships. Stakeholders such as research institutions (RI) need more involvement to amplify the benefits of adopting an IS through innovative waste solutions.

The stakeholders' network should attract experts on technical and social aspects of biowaste-to-resource innovation and train regional governance officers in emerging technologies to increase regional capacity. Some local authorities should be more associated with building capacity to support companies to seek opportunities among themselves (Velenturf & Jensen, 2016).

Flexible, progressive, participatory frameworks such as the TM, in which companies and regulatory agencies co-produce plans to implement strategies for waste-to-resource developments, are crucial (Breman et al., 2008).

6.3.2 Pathways

The transition arena is a phase that can be used as a jumping-off point for learning and demonstrating a visible action that is accessible, encourages debates and discussions that change people's thoughts and perceptions, and can be adopted and owned by the community (Peterson et al., 2022). This action, in turn, would result in experiments that might present a higher percentage of collaboration between the different stakeholders and would ensure a more effective transition.

Despite not having a large group of stakeholders collaborating in facilitating these processes, the fact that they have the same challenges and problems that arise in the transition to an IS suggests that the same transition pathways are shared. As both regions have the same objective of achieving waste-to-resource exchanges, these pathways (i.e., waste, resource and organisational) can be incorporated cross-cutting into the strategies and experiments, strengthening technical and organisational capacities in the transition.

The industrial origin of the region and the possibility of finding synergies are the factors that determine these pathways. The region is particularly notable for serving as an early focus location for the industrial ecosystem idea in the UK. It supports 20% of national gas landings, while the area accounts for 27% of UK CO2 emissions (Penn et al., 2014). However, not having pathways that allow negotiation, cooperation and shared interests to flourish has taken its toll on achieving transition objectives in the Humber region.

One of the strengths of the TM that have been observed in the Basque country has been the participation and inclusion of a wide range of stakeholders. Although the synergies achieved in Humber resulted from the adoption of novel ideas because of the commercial potential of the symbiosis, the failure to perform representation from more sectors prevented it from tackling cross-cutting and cross-sectoral issues.

6.4 Transition agenda

In the Humber region, it has been observed that the various incentives to promote IS were an essential strategy, coinciding with the type of strategy **S1** in the TM framework (Table 26). The fact that it was government-funded alleviated some of the inherent scepticism businesses had about working together since they recognised that an impartial authority oversaw it. The local administration is more interested in facilitating IS as they see it as an opportunity to accelerate a regenerative economy that supports local economies.

According to the interviewees, it proposes a new vision of IS in which the context should be based on various materials at any geographical distance. Given externalities such as Brexit and Covid-19, local authorities see IS as a cost-effective way forward. However, to prevent a failed transition, there is a need to talk to businesses and connect with different stakeholders in the value chain to realise symbiosis. The industrial landscape has changed, and elements that were successful in the past may not be successful if they were to be implemented again as the industrial ecosystem evolves.

Similarly, strategies such as the procurement of goods and services with circularity criteria helped to promote IS **(S2)**, the establishment of alliances between different stakeholders to increase synergies **(S3),** and accurate diagnostics on industrial waste (S4) coincide with those proposed in the TM framework. There have been cases where companies continued to promote IS and have made it a strategic element in their business model. The necessity for businesses to enhance their environmental performance (Jiao & Boons, 2014), institutional framework, governance arrangements, and solid commercial potential were deemed crucial (Abreu & Ceglia, 2018; Lombardi & Laybourn, 2012).

One reason why the success of IS in its early days is attributed to companies being forced to stop sending waste via increasingly expensive landfilling **(S5)**. This more environmentally focused strategy and a strategy geared towards commercial success are among the most prominent reasons for some regional symbiosis projects. The development of this strategy enabled **S6** and **S8** to

establish networks so that waste could be reused. Markets such as biodiesel production developed through NISP have seen an opportunity and have grown. Agriculture, waste aggregators, biodiesel production, and construction, all of which have a wide range of inputs and outputs, were determined to be highly central, along with the port, a critical link in supply chains and industries that cycle materials from waste to resource (Figure 20) (Penn et al., 2014).

On the other hand, two strategies (S12 and S13) have been found in the Humber region regarding the resource's pathway. These strategies are more related to the incorporation into the value chain of waste converted into resources. The Humber area has established excellent knowledge in waste-to-resource technologies due to its involvement in initiatives to promote IS for over a decade (Jensen, Basson, Hellawell, & Leach, 2012; Mirata, 2004; Velenturf, 2016). As a result, it has established excellent knowledge in waste-to-resource technologies due to its involvement in initiatives to promote IS for over a decade (Jensen, Basson, Hellawell, & Leach, 2012; Mirata, 2004; Velenturf, 2016). For instance, the public and private drive to implement waste-to-resource innovations in the bioenergy industry made the Humber region ideal for contributing to innovation progress towards IS.

Strategies such as **S7** (legal aspects), **S9** (extended producer responsibility), **S10** (refurbishment), **S11** (tax incentives), and **S14** (eco-design) have not been found within the strategies initially observed in the Humber region. However, strategy **S10** has been recorded in the experiments phase of this thesis. This could indicate that the continuity of the symbiosis in some cases has allowed strategies not initially in the programme to emerge ten years later from a bottom-up approach. Furthermore, it would be expected that as the concept of IS consolidates in a CE, strategies that were not used then, such as eco-design and refurbishment, will become more relevant.

6.5 Transition experiments

This disruption at the beginning of the NISP programme is reflected in the fact that few stakeholders carry out the implementation of the IS programmes to the present time, represented chiefly by companies and business associations.

Consequently, once the financing of the IS programme stopped, these stakeholders could not continue with it as the commercial interest did not bring any potential opportunity to profit. Nonetheless, some industries continued the IS after the funding was shut down because a) there was a clear commercial incentive to pursue them and b) defined collaboration roles among the various stakeholders that made symbiosis possible.

Table 28 recaps the types of experiments developed by the different stakeholders and those in which they have been indirectly involved. The following experiments (Table 28) are not intended to be an exhaustive list of all the IS projects underway in the Humber region. However, as many interviewees are still closely linked to the original program, either directly or indirectly, their responses reveal a snapshot of the IS network.

Companies and government entities stand out as the type of stakeholders that have led the highest percentage of transition experiments (90.32%) in the region. The experiments promoted the most by the companies have been related to partnerships in the chemical and manufacturing sectors, such as cooperation to carry out projects or to establish a cooperation framework that allows synergies to be implemented. Also, pilot projects in industries such as bioenergy that serve as examples to be scalable or demonstration projects in the glass industry that can be useful in the cement industry are among the symbiosis projects in the works.

Table 28. Transition experiments in the Humber region

	Experiments	Chemical	Industry-wide	Manufacturing	Renewable Energy	Services
Businesses	Innovation project	1.6%			1.6%	
	Landfill diversion					1.6%
	Methodology					1.6%
	Partnerships	3.2%		6.5%	1.6%	
	Pilot project		1.6%	3.2%		3.2%
	Procurement			1.6%		
	Remanufacturing project			1.6%		
	Reports					1.6%
	Research project			8.1%		1.6%

	Experiments	Chemical	Industry-wide	Manufacturing	Renewable Energy	Services
	Technological innovation	1.6%			3.2%	
	Training					1.6%
	Waste characterisation			1.6%	1.6%	1.6%
	Waste market	1.6%		3.2%		
	Waste recovery project	3.2%	3.2%		1.6%	
	Workshops					1.6%
Business associations	Grants		1.6%			
Local administration	Economic incentive scheme	1.6%				
	Grants		1.6%			3.2%
	Partnerships		1.6%			4.8%
	Procurement		1.6%			
	Reports		1.6%			
	Research project			1.6%		
	Training		3.2%			
	Waste recovery project					1.6%
	Workshops		1.6%			
Research institutions	Partnerships		1.6%			
	Pilot project		1.6%			
	Technological innovation		1.6%			
	Waste characterisation		1.6%			
	Waste market		1.6%			

Other experiments mentioned are research projects by universities or consortia of research centres. Typically, these experiments seek to find potential uses for certain materials that can be recirculated within the business fabric. Typically, the experiments were developed on a laboratory scale to test the feasibility of these wastes having a better use than being sent to the landfill without considering any commercial applicability. On the other hand, the experiments that refer to waste recovery projects allude to materials with sufficient volume to have commercial scalability. Thus, using the methods already established in companies, new alternatives are emerging for waste management, such as obtaining biofuels from food waste or obtaining 'green chemicals' in the lime industry.

On top of that, the experiments carried out by governmental entities are related to partnerships, which makes sense, given their role as critical participants in the transition. This type of experiment is focused on achieving regional economic development through this type of governmental strategy and as a stakeholder that guarantees collaboration between companies.

It is also understandable that if governments are involved in partnership issues, they will be involved in experiments like grants. The government invests in different initiatives to create synergies to impact the most significant number of organisations. Similarly, experiments such as training through support programs for companies and increasing the capabilities and skills of the workforce in industries such as the turbine blade manufacturing plant in Humber stand out.

Therefore, to understand the experiments mobilised among the different stakeholders, a comparison of the experiments carried out with and without cooperation across stakeholders is made. Table 29 shows that research institutions have the highest percentage of collaboration with companies.

Table 29. Collaboration between stakeholders

	Businesses	Business associations	Local administration	Research institutions	No cooperation
Businesses	34%	10%	5%	15%	37%
Business associations	0%	0%	100%	0%	0%
Local administration	40%	27%	13%	7%	13%
Research institutions	80%	0%	0%	20%	0%

As shown in Table 28, these experiments are more related to research projects with possible industrial applications. Also, business associations collaborate exclusively with local governmental agents. This collaboration explained the existence of the business associations, which serve as a bridge to funnel local funds to businesses. 34% of businesses collaborate with other businesses, while 37% of the IS experiments are conducted without cooperation between stakeholders.

The transition experiments shown here demonstrate how local governments and businesses have been the principal promoters of experiments. Without an overarching facilitator, the experiments currently undertaken in the Humber region are fragmented and without much multi-stakeholder traction. A commitment sustained solely by a commercial objective has meant that a lack of support and continuity of public policy, especially funding, can be seen as the elements that have not allowed the initial vision to continue growing in this part of the transition. Another problem has been the slow pace at which environmental regulations are not evolving at the same pace as technological innovation.

As the objective of any transition is to bring together those stakeholders who can enable the transition, having only some stakeholder groups would suggest that they are not yet mobilising the necessary stakeholders for this stage to consolidate the transition. Transition promoters and collaborators should be composed of stakeholders who build trusting relationships between the parties better to understand companies' commercial interests in resource synergies. The role of the promoter in carrying out experiments should be a third party, as in the Basque Country, that targets companies to help the transition in the long term. The role of the collaborator must be to build confidence in the value chain.

6.6 Transition monitoring

As observed in the previous section, a transition is not consolidated in the Humber region despite their know-how. The problem businesses and local authorities face is that much of the waste is not being monitored as there is no obligation. This lack of monitoring prevents the proper governance of the IS network as the industrial diversity of the area, and its materials are unknown.

The challenge for companies must be to make the business case for the transition, such as finding commercial viability to the symbiosis model as the waste exchange is not accessible for customers and recipients anymore, which helped drive the IS model in the past (Dóci et al., 2022). Therefore, once funding for the program stopped, there was no further evaluation of previous processes or experiments that would allow changes to the agenda or arena.

Nevertheless, in this part of the analysis of the transition in the Humber region, monitoring is based on the lessons learned from the experiments in the present time with some stakeholders from NISP. As there is a disconnection between experiments and others stages of the transition in the region due to funding cuts, adjustments to the agenda and vision do not affect each other.

As has been the case in the Basque Country, there are no robust baseline indicators with several years of data to assess the transition process to an IS. However, some stakeholders in the Humber region have suggested indicators that can be used in the process. The stakeholders were asked about the monitoring indicators they proposed or used to evaluate their progress (Table 30).

Table 30. Monitoring indicators

Stakeholders	Sector	Monitoring
Businesses	Services	Tonnage moved
Business associations	Services	Carbon emissions Waste diverted from landfill
Local administration	Industry-wide	Design of new products

It should be noted that these indicators have not been tested in the field as were the indicators tested in the Basque Country. These indicators were mentioned and considered by stakeholders in the Humber region due to their vast experience in IS. From the business stakeholders, the indicator of tonnes moved was the only one suggested. Although it is not an indicator present in the TM framework, it reflects in part the objective of many stakeholders to make waste management a key sector in the transition to SI within a CE. This suggestion occurred ten years ago and may be related to the close relationship between IS and CE nowadays, which would allow the waste management sector to be included as a relevant stakeholder in the services sector in the transition (Abreu & Ceglia, 2018).

On the other hand, business associations have suggested carbon emissions and waste diverted from landfill as indicators. Monitoring indicators suggested

or used by stakeholders, such as carbon emissions tracking, could be cross-cutting if they were part of the transition evaluation. The latter would be the one most closely related to the indicators proposed in the TM framework. This is because the recycling indicators proposed in the TM framework seek to measure precisely how much material has been diverted from landfill through recycling (Table 26).

Finally, the local administration has suggested developing new products as an indicator. This indicator is not included in the TM framework. However, the eco-design strategy (Table 26) does appear in the TM framework, which could lead to the use for measurement of this strategy as suggested by the stakeholders in Humber. One reason this indicator in IS has perhaps gone unnoticed could be due to the lack of research on the topic (see Figure 2), as shown in the semantic network of the topic. It is important to note that the key to the indicators is their focus on measuring the capacity to generate waste that can be converted into resources, as shown in section 5.6.

7

Conclusions, Limitations and Future Research

This chapter summarises the outcomes and main conclusions obtained from this research. Moreover, it presents the main limitations of the TM framework for an IS. Finally, it proposes future research lines to address the existing limitations and increase the TM framework's positive impact on an orderly transition.

7.1 Conclusions

This thesis has aimed to integrate and use concepts and learn from the emerging area of TM to systematically investigate how to move from a linear system to a more sustainable mode of production. The concepts of the TM framework have been applied to analyse IS systems, and the four cycles of the TM framework have been used to analyse the processes that have taken place in two regions.

Based on the results of this thesis, it could be said that the transition towards an IS-focused CE system could be governed if specific criteria of the TM framework that this thesis has developed throughout the different chapters are followed. Even though a transition cannot be governed if these stakeholders are not found in a defined system, it is essential that they are willing to form a transition network and that in its initial stage (arenas and agenda), the manager's role is defined.

Otherwise, trust building and partnership building will be more complex and not sustainable over time. Equally, more transition pathways are likely to emerge. However, this thesis has found that when it comes to IS, the most frequent problems and solutions to be addressed will be governed by these pathways (organisational, waste and resource).

This thesis has followed the line drawn by the transition pathways; therefore, 14 strategies have been prioritised. In some case studies, more strategies may be prioritised. However, in this case, these strategies were contrasted with the literature, and it seems they are the most common barriers that transition stakeholders must address.

Likewise, strategies serve to develop experiments, which are actions that are implemented in the short and medium term. Twenty actions needed to guide the transition should be considered when facilitating the transition. More importantly, these actions should be accompanied by stakeholders who should play specific roles to ensure that the transition network can be appropriately governed. In this thesis, two roles have been identified: the promoters and the collaborators. Although it is recommended that these roles are not pre-

determined for the stakeholders, it would be vital that companies and all those stakeholders who control waste and resources lead these experiments. However, looking at the evidence in the literature, collaboration must be broad and promoted by other stakeholders outside the control of waste and resources, such as social organisations or research institutions, to ensure a complete transition. It is essential to conclude that the types of experiments related to resource pathways should become more relevant, especially those that foster innovation, eco-design, and any other experimentation whose action is reincorporating waste into the value chain.

Finally, the transition can be measured through 14 indicators. Although these indicators are not intended to cover all the elements to be measured in the transition, they should monitor waste generation and reincorporation into the value chain. Also, in line with the previous phase, indicators measuring whether research, development and innovation are facilitating the transition will play a key role in measuring the transition.

To conclude, it can be said that the transition towards a CE framed within a system of IS can be governed if the TM framework is considered a viable facilitation guide. Therefore, the process of facilitating the transition can be enabled if the evidence in this thesis follows. Although the TM framework is not a total solution to the problems that gave rise to this thesis, it is fair to say that a model like the one proposed here can help manage the transition processes better to create value for business and society. Hopefully, this thesis has shed light on the lack of understanding of how multiple stakeholders can address and influence the desired changes in the face of the growing environmental and social problems that led to a transition process. Nevertheless, issues such as more funding and the commitment of more stakeholders to participate in the visioning process could help strengthen the transition.

7.2 Limitations

The Transition Management framework defined in this research is limited in various ways. Following, the main limitations of this research are presented:

- One limitation of this study is its focus on two regions. Although the regions are highly industrialised, which is an essential factor in implementing IS, it may not be as relevant in regions with low levels of industrialisation. Nevertheless, these strategies might be extrapolated to other regions, assuming that the transition towards a CE is part of the strategic vision in that region. So, these strategies could be transferred to a more operational level that offers tangible and scalable evidence that motivates more participants to remain part of the transition.
- This thesis focuses on industrial sectors with a downstream focus (waste as a resource) more relevant than an upstream approach (avoiding waste in the first place). Eliminating the concept of waste play a critical role as a waste-to-resource exchange may help speed up this transition. So, it is necessary to stimulate an industry environment that is reluctant to accept this paradigm change, which this thesis does not address.
- To enhance the evaluation process of the transition, a robust baseline must be set to monitor improvements in transitioning to this new model, including different sectors, such as banking and services, among others, to assess the applicability of this set of indicators. This baseline will lead to consistent measurement frameworks that will enable data-driven decision-making and progress-tracking and ultimately justify the value of the transition framework.

7.3 Future research

Future study will focus on overcoming the limits of the preceding section's research and, as a result, improving the TM framework:

- The framework contributes to facilitating the transition toward IS systems. Transition research mainly depends on empirical material to provide proof of its actual "transformational" significance (Schot &

Kanger, 2018). So, more data on variation in CE implementation is needed to address interactions, connections, trade-offs, and mismatches between technology and socio-institutional systems. Mainly how IS's collaboratively oriented experimental environment interacts most effectively and how interrelationships should be constructed to produce compatible and successful outcomes.

- Further research is suggested to analyse the many micropolitics, power, and agency in experimentation. This suggestion covers how discussions and disputes between experimentation players evolve and how their access to resources and respective relational positions determine their capacity to influence the design and outcome of experimentation.
- Include more empirical studies with quantitative techniques and approaches to uncover trends. These empirical studies may comprehensively identify experiments' critical success and failure factors and use network analysis to understand how they are connected across locations and flow types. Moreover, it will offer explicit, unambiguous, and coherent system representations, aid in concluding the elements and processes behind emergent phenomena and permit systematic experimentation.

REFERENCES

Abreu, M. C. S. de, & Ceglia, D. (2018). On the implementation of a circular economy: The role of institutional capacity-building through industrial symbiosis. *Resources, Conservation and Recycling*, *138*(June), 99–109. https://doi.org/10.1016/j.resconrec.2018.07.001

Aguilar-Hernandez, G. A., Sigüenza-Sanchez, C. P., Donati, F., Merciai, S., Schmidt, J., Rodrigues, J. F. D., & Tukker, A. (2019). The circularity gap of nations: A multiregional analysis of waste generation, recovery, and stock depletion in 2011. *Resources, Conservation and Recycling*, *151*(November 2018), 104452. https://doi.org/10.1016/j.resconrec.2019.104452

Aid, G., Eklund, M., Anderberg, S., & Baas, L. (2017). Expanding roles for the Swedish waste management sector in inter-organizational resource management. *Resources, Conservation and Recycling*, *124*(March 2016), 85–97. https://doi.org/10.1016/j.resconrec.2017.04.007

Albino, V., Fraccascia, L., & Giannoccaro, I. (2016). Exploring the role of contracts to support the emergence of self-organized industrial symbiosis networks: an agent-based simulation study. *Journal of Cleaner Production*, *112*, 4353–4366.

Álvarez, R., & Ruiz-Puente, C. (2017). Development of the Tool SymbioSyS to Support the Transition Towards a Circular Economy Based on Industrial Symbiosis Strategies. *Waste Biomass Valori.*, *8*(5), 1521–1530. https://doi.org/10.1007/s12649-016-9748-1

Ashton, W. (2008). Understanding the organization of industrial ecosystems: A social network approach. *Journal of Industrial Ecology*, *12*(1), 34–51. https://doi.org/10.1111/j.1530-9290.2008.00002.x

Ashton, W. S. (2009). The structure, function, and evolution of a regional industrial ecosystem. *Journal of Industrial Ecology*, *13*(2), 228–246. https://doi.org/10.1111/j.1530-9290.2009.00111.x

Ashton, W. S. (2011). Managing performance expectations of industrial symbiosis. *Business Strategy and the Environment*, *20*(5), 297–309. https://doi.org/doi.org/10.1002/bse.696

Ashton, W. S., & Bain, A. C. (2012). Assessing the "short mental distance" in eco-industrial networks. *Journal of Industrial Ecology*, *16*(1), 70–82.

https://doi.org/10.1111/j.1530-9290.2011.00453.x

Baas, L. (2011). Planning and uncovering industrial symbiosis: comparing the Rotterdam and Östergötland regions. *Business Strategy and the Environment*, *20*(7), 428–440. https://doi.org/10.1002/bse.735

Baas, L., & Boons, F. (2007). The introduction and dissemination of the industrial symbiosis projects in the Rotterdam Harbour and Industry Complex. *International Journal of Environmental Technology and Management*, *7*(5–6), 551–577. https://doi.org/10.1504/ijetm.2007.015630

Baas, L. W., & Korevaar, G. (2010). Eco-Industrial Parks in the Netherlands: The Rotterdam Harbor and Industry Complex. *Sustainable Development in the Process Industries, Wiley, Hoboken, NJ*, 59–79. https://doi.org/doi:10.1002/9780470586099.ch5

Bacudio, L. R., Benjamin, M. F. D., Eusebio, R. C. P., Holaysan, S. A. K., Promentilla, M. A. B., Yu, K. D. S., & Aviso, K. B. (2016). Analyzing barriers to implementing industrial symbiosis networks using DEMATEL. *Sustainable Production and Consumption*, *7*, 57–65. https://doi.org/doi.org/10.1016/j.spc.2016.03.001

Bain, A., Ashton, W., & Shenoy, M. (2009). Resource reuse and recycling in an Indian industrial network: efficiency and flexibility considerations. *2009 Second International Conference on Infrastructure Systems and Services: Developing 21st Century Infrastructure Networks (INFRA)*, 1–7. https://doi.org/10.1109/INFRA.2009.5397868

Bain, A., Shenoy, M., Ashton, W., & Chertow, M. (2010). Industrial symbiosis and waste recovery in an Indian industrial area. *Resources, Conservation and Recycling*, *54*(12), 1278–1287. https://doi.org/doi.org/10.1016/j.resconrec.2010.04.007

Baldassarre, B., Schepers, M., Bocken, N., Cuppen, E., Korevaar, G., & Calabretta, G. (2019). Industrial Symbiosis: towards a design process for eco-industrial clusters by integrating Circular Economy and Industrial Ecology perspectives. *Journal of Cleaner Production*, *216*, 446–460. https://doi.org/10.1016/j.jclepro.2019.01.091

Barbier, L., Simoens, S., Declerck, P., Vulto, A. G., & Huys, I. (2022). Biosimilar use and switching in Belgium: Avenues for integrated policy makin. *Frontiers in Pharmacology*, *13*(July), 1–15. https://doi.org/10.3389/fphar.2022.821616

Barón Dorado, A., Giménez Leal, G., & de Castro Vila, R. (n.d.). Environmental policy and corporate sustainability: The mediating role of environmental

management systems in circular economy adoption. *Corporate Social Responsibility and Environmental Management*. https://doi.org/doi.org/10.1002/csr.2238

Barreiro-Gen, M., & Lozano, R. (2020). How circular is the circular economy? Analysing the implementation of circular economy in organisations. *Business Strategy and the Environment*, *June*, 1–11. https://doi.org/10.1002/bse.2590

Bassi, F., & Dias, J. G. (2019). The use of circular economy practices in SMEs across the EU. *Resources, Conservation and Recycling*, *146*, 523–533. https://doi.org/10.1016/j.resconrec.2019.03.019

Beers, D., Bossilkov, A., Corder, G., & Berkel, R. (2008). Industrial Symbiosis in the Australian Minerals Industry: The Cases of Kwinana and Gladstone. *Journal of Industrial Ecology*, *11*(1), 55–72. https://doi.org/10.1162/jiec.2007.1161

Behera, S. K., Kim, J.-H., Lee, S.-Y., Suh, S., & Park, H.-S. (2012). Evolution of 'designed' industrial symbiosis networks in the Ulsan Eco-industrial Park: 'research and development into business' as the enabling framework. *Journal of Cleaner Production*, *29–30*, 103–112. https://doi.org/10.1016/j.jclepro.2012.02.009

Belaud, J.-P., Adoue, C., Vialle, C., Chorro, A., & Sablayrolles, C. (2019). A circular economy and industrial ecology toolbox for developing an eco-industrial park: perspectives from French policy. *Clean Technologies and Environmental Policy*, *21*(5), 967–985. https://doi.org/10.1007/s10098-019-01677-1

Bezama, A., Ingrao, C., O'Keeffe, S., & Thrän, D. (2019). Resources, collaborators, and neighbors: The three-pronged challenge in the implementation of bioeconomy regions. *Sustainability (Switzerland)*, *11*(24). https://doi.org/10.3390/su11247235

Bian, Y., Dong, L., Liu, Z., & Zhang, L. (2020). A sectoral eco-efficiency analysis on urban-industrial symbiosis. *Sustainability*, *12*(9), 3650. https://doi.org/10.3390/su12093650

Bidmon, C. M., & Knab, S. F. (2018). The three roles of business models in societal transitions: New linkages between business model and transition research. *Journal of Cleaner Production*, *178*, 903–916. https://doi.org/10.1016/j.jclepro.2017.12.198

Boons, F. (2009). Creating ecological value: An evolutionary approach to business strategies and the natural environment. In *Edward Elgar Publishing*.

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. https://doi.org/10.1111/jiec.12468

Bornmann, L. (2011). Scientific peer review. *Annual Review of Information Science and Technology*, *45*(1), 197–245. https://doi.org/10.1002/aris.2011.1440450112

Branca, T. A., Fornai, B., Colla, V., Pistelli, M. I., Faraci, E. L., Cirilli, F., & Schröder, A. J. (2021). Industrial symbiosis and energy efficiency in European process Industries: A review. *Sustainability*, *13*(16), 9159. https://doi.org/10.3390/su13169159

Branson, R. (2016). Re-constructing Kalundborg: the reality of bilateral symbiosis and other insights. *Journal of Cleaner Production*, *112*, 4344–4352. https://doi.org/10.1016/j.jclepro.2015.07.069

Breman, B. C., Pleijte, M., Ouboter, P. S. H., & Buijs, A. E. (2008). *Participatie in waterbeheer: een vak apart*.

Briner, R. B., & Denyer, D. (2012). Systematic review and evidence synthesis as a practice and scholarship tool. *Handbook of Evidence-Based Management: Companies, Classrooms and Research*, 112–129. https://doi.org/10.1093/oxfordhb/9780199763986.013.0007

Brown, P. J., & Bajada, C. (2018). An economic model of circular supply network dynamics: Toward an understanding of performance measurement in the context of multiple stakeholders. *Business Strategy and the Environment*, *27*(5), 643–655. https://doi.org/10.1002/bse.2069

Browne, K. (2005). Snowball sampling: using social networks to research non-heterosexual women. *International Journal of Social Research Methodology*, *8*(1), 47–60.

Carson, D., Gilmore, A., Perry, C., & Gronhaug, K. (2011). Focus Group Interviewing. In *Qualitative Marketing Research*. https://doi.org/10.4135/9781849209625.n8

Carvalho, M. M., Fleury, A., & Lopes, A. P. (2013). An overview of the literature on technology roadmapping (TRM): Contributions and trends. *Technological Forecasting and Social Change*, *80*(7), 1418–1437. https://doi.org/10.1016/j.techfore.2012.11.008

Ceglia, D., Abreu, M. C. S. de, & Da Silva Filho, J. C. L. (2017). Critical elements for eco-retrofitting a conventional industrial park: Social barriers to be overcome. *Journal of Environmental Management*, *187*, 375–383. https://doi.org/10.1016/j.jenvman.2016.10.064

Cerceau, J., Mat, N., Junqua, G., Lin, L., Laforest, V., & Gonzalez, C. (2014). Implementing industrial ecology in port cities: International overview of case studies and cross-case analysis. *Journal of Cleaner Production*, *74*, 1–16. https://doi.org/10.1016/j.jclepro.2014.03.050

Cervo, H., Ogé, S., Maqbool, A. S., Mendez Alva, F., Lessard, L., Bredimas, A., Ferrasse, J.-H., & Van Eetvelde, G. (2020). A case study of industrial symbiosis in the Humber region using the EPOS methodology. *Sustainability*. https://doi.org/10.3390/su11246940

Chari, A., Niedenzu, D., Despeisse, M., Machado, C. G., Azevedo, J. D., Boavida-Dias, R., & Johansson, B. (2022). Dynamic capabilities for circular manufacturing supply chains—Exploring the role of Industry 4.0 and resilience. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3040

Charmaz, K., & Liska, L. (2013). Grounded theory. *Qualitative Research in the Health Sciences: Methodologies, Methods and Processes*, *9780203777*, 30–55. https://doi.org/10.4324/9780203777176

Chen, C.-W. (2020). Improving Circular Economy Business Models: Opportunities for Business and Innovation: A new framework for businesses to create a truly circular economy. *Johnson Matthey Technology Review*, *64*(1), 48–58. https://doi.org/https://doi.org/10.1595/205651320X15716663479155

Chertow. (2000). Industrial symbiosis: Literature and Taxonomy. *Annual Review of Energy and the Environment*, *25*(November), pp 313-337. https://doi.org/10.1146/annurev.energy.25.1.313

Chertow, & Ehrenfeld, J. (2012). Organizing Self-Organizing Systems: Toward a Theory of Industrial Symbiosis. *Journal of Industrial Ecology*, *16*(1), 13–27. https://doi.org/10.1111/j.1530-9290.2011.00450.x

Chertow, M. R. (2007). "Uncovering" industrial symbiosis. *Journal of Industrial Ecology*, *11*(1), 11–30. https://doi.org/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. https://doi.org/10.1080/00343400701874123

Chopra, S. S., & Khanna, V. (2014). Understanding resilience in industrial symbiosis networks: Insights from network analysis. *Journal of Environmental Management*, *141*, 86–94. https://doi.org/10.1016/j.jenvman.2013.12.038

Circle Economy. (2018). *The circularity gap report* (Issue January). https://www.circle-economy.com/resources/the-circularity-gap-report-

our-world-is-only-9-circular

Circle Economy. (2019). *The circularity gap report*. https://docs.wixstatic.com/ugd/ad6e59_ba1e4d16c64f44fa94fbd8708eae8e34.pdf

Cobo, S., Dominguez-ramos, A., & Irabien, A. (2018). From linear to circular integrated waste management systems : A review of methodological approaches. *Resources, Conservation & Recycling*, *135*(August 2017), 279–295. https://doi.org/10.1016/j.resconrec.2017.08.003

Corona, B., Shen, L., Reike, D., Rosales Carreón, J., & Worrell, E. (2019). Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. *Resources, Conservation and Recycling*, *151*(September), 104498. https://doi.org/10.1016/j.resconrec.2019.104498

Costa, I., & Ferrão, P. (2010). A case study of industrial symbiosis development using a middle-out approach. *Journal of Cleaner Production*, *18*(10), 984–992. https://doi.org/10.1016/j.jclepro.2010.03.007

Costa, I., Massard, G., & Agarwal, A. (2010). Waste management policies for industrial symbiosis development: case studies in European countries. *Journal of Cleaner Production*, *18*(8), 815–822. https://doi.org/10.1016/j.jclepro.2009.12.019

Cramer, J. M. (2020a). Implementing the circular economy in the Amsterdam Metropolitan Area: The interplay between market actors mediated by transition brokers. *Business Strategy and the Environment*, *29*(6), 2857–2870. https://doi.org/10.1002/bse.2548

Cramer, J. M. (2020b). Practice-based model for implementing circular economy: The case of the Amsterdam Metropolitan Area. *Journal of Cleaner Production*, *255*, 120255. https://doi.org/10.1016/j.jclepro.2020.120255

Cramer, J. M. (2020c). The function of transition brokers in the regional governance of implementing circular economy - A comparative case study of six dutch regions. *Sustainability (Switzerland)*, *12*(12). https://doi.org/10.3390/su12125015

Daddi, T., Nucci, B., & Iraldo, F. (2017). Using Life Cycle Assessment (LCA) to measure the environmental benefits of industrial symbiosis in an industrial cluster of SMEs. *Journal of Cleaner Production*, *147*, 157–164. https://doi.org/10.1016/j.jclepro.2017.01.090

de Jesus, A., & Mendonça, S. (2018). Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy. *Ecological Economics*,

145(December 2016), 75–89. https://doi.org/10.1016/j.ecolecon.2017.08.001

de Oliveira, F. R., França, S. L. B., & Rangel, L. A. D. (2018). Challenges and opportunities in a circular economy for a local productive arrangement of furniture in Brazil. *Resources, Conservation and Recycling*, *135*, 202–209. https://doi.org/10.1016/j.resconrec.2017.10.031

de Souza, F. F., Ferreira, M. B., Saraceni, A. V., Betim, L. M., Pereira, T. L., Petter, R. R. H., Pagani, R. N., de Resende, L. M. M., Pontes, J., & Piekarski, C. M. (2020). Temporal comparative analysis of industrial symbiosis in a business network: Opportunities of circular economy. *Sustainability (Switzerland)*, *12*(5), 1–18. https://doi.org/10.3390/su12051832

de Souza, V., Bloemhof-Ruwaard, J., & Borsato, M. (2019). Towards regenerative supply networks: A design framework proposal. *Journal of Cleaner Production*, *221*, 145–156. https://doi.org/10.1016/j.jclepro.2019.02.178

Derks, M., Berkers, F., & Tukker, A. (2022). Toward Accelerating Sustainability Transitions through Collaborative Sustainable Business Modeling: A Conceptual Approach. *Sustainability (Switzerland)*, *14*(7). https://doi.org/10.3390/su14073803

Di Maio, F., Rem, P. C., Baldé, K., & Polder, M. (2017). Measuring resource efficiency and circular economy: A market value approach. *Resources, Conservation and Recycling*, *122*, 163–171. https://doi.org/10.1016/j.resconrec.2017.02.009

DiCicco-Bloom, B., & Crabree, B. F. (2006). The qualitative research interview. *Qualitative Research in Accounting and Management*, *40*(3), 314–321. https://doi.org/10.1108/11766091111162070

Dóci, G., Rohracher, H., & Kordas, O. (2022). Knowledge management in transition management: The ripples of learning. *Sustainable Cities and Society*, *78*(December 2021). https://doi.org/10.1016/j.scs.2021.103621

Domenech, T., & Bahn-Walkowiak, B. (2019). Transition Towards a Resource Efficient Circular Economy in Europe: Policy Lessons From the EU and the Member States. *Ecological Economics*, *155*, 7–19. https://doi.org/10.1016/j.ecolecon.2017.11.001

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*(August 2018), 76–98. https://doi.org/10.1016/j.resconrec.2018.09.016

Domenech, T., & Davies, M. (2011). Structure and morphology of industrial

symbiosis networks: The case of Kalundborg. *Procedia - Social and Behavioral Sciences*, *10*, 79–89. https://doi.org/10.1016/j.sbspro.2011.01.011

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. https://doi.org/10.1002/bse.695

Dong, H., Ohnishi, S., Fujita, T., Geng, Y., Fujii, M., & Dong, L. (2014). Achieving carbon emission reduction through industrial & urban symbiosis: A case of Kawasaki. *Energy*, *64*, 277–286. https://doi.org/10.1016/j.energy.2013.11.005

Dong, L., Fujita, T., Dai, M., Geng, Y., Ren, J., Fujii, M., Wang, Y., & Ohnishi, S. (2016). Towards preventative eco-industrial development: an industrial and urban symbiosis case in one typical industrial city in China. *Journal of Cleaner Production*, *114*, 387–400. https://doi.org/10.1016/j.jclepro.2015.05.015

Ellen MacArthur Foundation. (2013). Towards the Circular Economy. *Ellen MacArthur Foundation*, *1*, 1–96. https://doi.org/10.1162/108819806775545321

Esposito, M., Tse, T., & Soufani, K. (2018). Introducing a Circular Economy: New Thinking with New Managerial and Policy Implications. *California Management Review*, *60*(3), 5–19. https://doi.org/10.1177/0008125618764691

European Commission. (2010). SMEs and the environment in the European Union. *European Comission*.

European Commission. (2018). *Measuring progress towards circular economy in the European Union – Key indicators for a monitoring framework*.

European Commission. (2019). *Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - on the implementation of the Circular Economy Action Plan*.

European Commission. (2020a). *A new Circular Economy Action Plan For a cleaner and more competitive Europe*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0098&from=EN

European Commission. (2020b). *Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions. A new Circular Economy Action Plan For a cleaner and more competitive Europe*. COM/2020/98 Final. https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF

European Commission, & ARCTIK SPRL-Environmental Communications.

(2017). *EC - Public procurement for a circular economy*. http://ec.europa.eu/environment/gpp/pdf/CP_European_Commission_Brochure_webversion_small.pdf

European Union. (1994). European Parliament and Council Directive 94/62/EC. *Official Journal of the European Communities*, *1993*(L), 10–23. https://doi.org/10.1038/sj.bdj.4811054

Evans, S., Benedetti, M., & Holgado Granados, M. (2017). *Library of Industrial Symbiosis case studies and linked exchanges*. https://doi.org/https://doi.org/10.17863/CAM.12608

Fan, Y., Qiao, Q., & Fang, L. (2017). Network analysis of industrial metabolism in industrial park – A case study of Huai'an economic and technological development area. *Journal of Cleaner Production*, *142*, 1552–1561. https://doi.org/10.1016/j.jclepro.2016.11.149

Feiferytė-Skirienė, A., & Stasiškienė, Ž. (2021). Seeking Circularity: Circular Urban Metabolism in the Context of Industrial Symbiosis. *Sustainability*, *13*(16), 9094. https://doi.org/10.3390/su13169094

Ferreira, I. de A., Fraga, M. de C., Godina, R., Barreiros, M. S., & Carvalho, H. (2019). A proposed index of the implementation and maturity of circular economy practices-the case of the pulp and paper industries of Portugal and Spain. *Sustainability (Switzerland)*, *11*(6). https://doi.org/10.3390/su11061722

Figge, F., & Thorpe, A. S. (2019). The symbiotic rebound effect in the circular economy. *Ecological Economics*, *163*(February), 61–69. https://doi.org/10.1016/j.ecolecon.2019.04.028

Figge, F., Thorpe, A. S., & Good, J. (2021). Us before me : A group level approach to the circular economy. *Ecological Economics*, *179*(September 2020), 106838. https://doi.org/10.1016/j.ecolecon.2020.106838

Fisher, O. J., Watson, N. J., Escrig, J. E., & Gomes, R. L. (2020). Intelligent resource use to deliver waste valorisation and process resilience in manufacturing environments. *Johnson Matthey Technology Review*, *64*(1). https://doi.org/10.1595/205651320x15735483214878

Flynn, A., Hacking, N., & Xie, L. (2019). Governance of the circular economy: A comparative examination of the use of standards by China and the United Kingdom. *Environmental Innovation and Societal Transitions*, *33*(August), 282–300. https://doi.org/10.1016/j.eist.2019.08.002

Fraccascia, L., Giannoccaro, I., & Albino, V. (2017). Efficacy of landfill tax and subsidy policies for the emergence of industrial symbiosis networks: An

agent-based simulation study. *Sustainability (Switzerland)*, *9*(4). https://doi.org/10.3390/su9040521

Fraccascia, L., Giannoccaro, I., & Albino, V. (2019). Business models for industrial symbiosis: A taxonomy focused on the form of governance. *Resources, Conservation and Recycling*, *146*(March), 114–126. https://doi.org/10.1016/j.resconrec.2019.03.016

Fraccascia, L., & Yazan, D. M. (2018). The role of online information-sharing platforms on the performance of industrial symbiosis networks. *Resources, Conservation and Recycling*, *136*(December 2017), 473–485. https://doi.org/10.1016/j.resconrec.2018.03.009

Freitas, L. A. R. U., & Magrini, A. (2017). Waste management in industrial construction: Investigating contributions from industrial ecology. *Sustainability (Switzerland)*, *9*(7), 6–8. https://doi.org/10.3390/su9071251

Friedman, A. L., & Miles, S. (2006). *Stakeholders: Theory and practice*. OUP Oxford.

Geels, F., & Schot, J. (2010). The Dynamics of Transitions: A Socio-Technical Perspective. In J. Grin, J. Rotmans, & J. Schot (Eds.), *Transitions to Sustainable Development: New directions in the Study of Long Term Transformative Change* (pp. 18–28). Routledge.

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. https://doi.org/10.1016/j.jclepro.2016.12.048

Genc, O. (2021). SymbioConstruction: A Bibliography-Driven Dynamic Construction Industry Symbiosis Database. *Journal of Construction Engineering and Management*, *147*(8), 4021077. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002095

Genc, O., van Capelleveen, G., Erdis, E., Yildiz, O., & Yazan, D. M. (2019). A socio-ecological approach to improve industrial zones towards eco-industrial parks. *Journal of Environmental Management*, *250*(September), 109507. https://doi.org/10.1016/j.jenvman.2019.109507

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving' leapfrog development'. *The International Journal of Sustainable Development & World Ecology*, *15*(3), 231–239. https://doi.org/10.3843/SusDev.15.3:6

Geng, Y., Sarkis, J., Ulgiati, S., & Zhang, P. (2013). Measuring China's circular economy. *Science*, *339*(6127), 1526–1527. https://doi.org/10.1126/science.1227059

Ghinoi, S., Silvestri, F., & Steiner, B. (2020). The role of local stakeholders in disseminating knowledge for supporting the circular economy: a network analysis approach. *Ecological Economics*, *169*(August 2019), 106446. https://doi.org/10.1016/j.ecolecon.2019.106446

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Ghisellini, P., & Ulgiati, S. (2020). Circular economy transition in Italy. Achievements, perspectives and constraints. *Journal of Cleaner Production*, *243*, 118360. https://doi.org/10.1016/j.jclepro.2019.118360

Golev, A., Corder, G. D., & Giurco, D. P. (2015). Barriers to industrial symbiosis: Insights from the use of a maturity grid. *Journal of Industrial Ecology*, *19*(1), 141–153. https://doi.org/10.1111/jiec.12159

Goodman, J., Korsunova, A., & Halme, M. (2017). Our Collaborative Future: Activities and Roles of Stakeholders in Sustainability-Oriented Innovation. *Business Strategy and the Environment*, *26*(6), 731–753. https://doi.org/10.1002/bse.1941

Gopinath, A., Bahurudeen, A., Appari, S., & Nanthagopalan, P. (2018). A circular framework for the valorisation of sugar industry wastes: Review on the industrial symbiosis between sugar, construction and energy industries. *Journal of Cleaner Production*, *203*, 89–108. https://doi.org/10.1016/j.jclepro.2018.08.252

Gordon, M., Lockwood, M., Vanclay, F., Hanson, D., & Schirmer, J. (2012). Divergent stakeholder views of corporate social responsibility in the Australian forest plantation sector. *Journal of Environmental Management*, *113*(0), 390–398. https://doi.org/10.1016/j.jenvman.2012.09.016

Graedel, T. E., & Allenby, B. R. (2010). *Industrial ecology and sustainable engineering*. Prentice Hall Upper Saddle River, NJ:

Granello, D. H., & Wheaton, J. E. (2004). Online data collection: Strategies for research. *Journal of Counseling & Development*, *82*(4), 387–393. https://doi.org/10.1002/j.1556-6678.2004.tb00325.x

Graymore, M. L. M., Sipe, N. G., & Rickson, R. E. (2008). Regional sustainability: How useful are current tools of sustainability assessment at the regional scale? *Ecological Economics*. https://doi.org/10.1016/j.ecolecon.2008.06.002

Gregson, N., Crang, M., Fuller, S., & Holmes, H. (2015). Interrogating the circular economy: the moral economy of resource recovery in the EU. *Economy and*

Society, *44*(2), 218–243. https://doi.org/10.1080/03085147.2015.1013353

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to sustainable development: new directions in the study of long term transformative change*. Routledge.

Guo, L., & Hu, X. (2011). Green technological trajectories in eco-industrial parks and the selected environment. *Journal of Knowledge-Based Innovation in China*. https://doi.org/10.1108/17561411111120873

Harris, S. (2007). Industrial symbiosis in the Kwinana industrial area (Western Australia). *Measurement and Control*, *40*(8), 239–244. https://doi.org/10.1177%2F002029400704000802

Hassannejad, Z., Sharif-Alhoseini, M., Shakouri-Motlagh, A., Vahedi, F., Zadegan, S. A., Mokhatab, M., Rezvan, M., Saadat, S., Shokraneh, F., & Rahimi-Movaghar, V. (2016). Potential variables affecting the quality of animal studies regarding pathophysiology of traumatic spinal cord injuries. *Spinal Cord*, *54*(8), 579–583. https://doi.org/10.1038/sc.2015.215

Hein, A. M., Jankovic, M., Feng, W., Farel, R., Yune, J. H., & Yannou, B. (2017). Stakeholder power in industrial symbioses: A stakeholder value network approach. *Journal of Cleaner Production*, *148*, 923–933. https://doi.org/10.1016/j.jclepro.2017.01.136

Hennink, M. M., & Leavy, P. (2015). Understanding Focus Group Discussions. In *Understanding Focus Group Discussions*. https://doi.org/10.1093/acprof:osobl/9780199856169.001.0001

Herczeg, G., Akkerman, R., & Hauschild, M. Z. (2018). Supply chain collaboration in industrial symbiosis networks. *Journal of Cleaner Production*, *171*, 1058–1067. https://doi.org/10.1016/j.jclepro.2017.10.046

Hofmann, F., & Jaeger-Erben, M. (2020). Organizational transition management of circular business model innovations. *Business Strategy and the Environment*, *May*, 2770–2788. https://doi.org/10.1002/bse.2542

Hölscher, K., Wittmayer, J. M., Avelino, F., & Giezen, M. (2019). Opening up the transition arena: An analysis of (dis)empowerment of civil society actors in transition management in cities. *Technological Forecasting and Social Change*, *145*(May 2017), 176–185. https://doi.org/10.1016/j.techfore.2017.05.004

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

Hyysalo, S., Lukkarinen, J., Kivimaa, P., Lovio, R., Temmes, A., Hildén, M., Marttila, T., Auvinen, K., Perikangas, S., Pyhälammi, A., Peljo, J., Savolainen,

K., Hakkarainen, L., Rask, M., Matschoss, K., Huomo, T., Berg, A., & Pantsar, M. (2019). Developing policy pathways: Redesigning transition arenas for mid-range planning. *Sustainability (Switzerland)*, *11*(3), 1–22. https://doi.org/10.3390/su11030603

Iacovidou, E., Hahladakis, J. N., & Purnell, P. (2021). A systems thinking approach to understanding the challenges of achieving the circular economy. *Environmental Science and Pollution Research*, *28*(19), 24785–24806. https://doi.org/10.1007/s11356-020-11725-9

Iacovidou, E., Velis, C. A., Purnell, P., Zwirner, O., Brown, A., Hahladakis, J., Millward-Hopkins, J., & Williams, P. T. (2017). Metrics for optimising the multi-dimensional value of resources recovered from waste in a circular economy: A critical review. *Journal of Cleaner Production*, *166*, 910–938. https://doi.org/10.1016/j.jclepro.2017.07.100

Jacobsen, N. B. (2006). Industrial symbiosis in Kalundborg, Denmark: a quantitative assessment of economic and environmental aspects. *Journal of Industrial Ecology*, *10*(1-2), 239–255. https://doi.org/10.1162/108819806775545411

Jakhar, S. K., Mangla, S. K., Luthra, S., & Kusi-Sarpong, S. (2019). When stakeholder pressure drives the circular economy: Measuring the mediating role of innovation capabilities. *Management Decision*, *57*(4), 904–920. https://doi.org/10.1108/MD-09-2018-0990

Janine, B. (2002). Biomimicry: Innovation inspired by nature. *Publish Harper Collins, New York*.

Jensen, P. D. (2016). The role of geospatial industrial diversity in the facilitation of regional industrial symbiosis. *Resources, Conservation and Recycling*, *107*, 92–103. https://doi.org/10.1162/108819806775545411

Jensen, P. D., Basson, L., Hellawell, E. E., & Leach, M. (2012). "Habitat" Suitability Index Mapping for Industrial Symbiosis Planning. *Journal of Industrial Ecology*, *16*(1), 38–50. https://doi.org/10.1111/j.1530-9290.2011.00438.x

Jiao, W., & Boons, F. (2014). Toward a research agenda for policy intervention and facilitation to enhance industrial symbiosis based on a comprehensive literature review. *Journal of Cleaner Production*, *67*, 14–25. https://doi.org/10.1016/j.jclepro.2013.12.050

Jolly, S., & Raven, R. P. J. M. (2015). Collective institutional entrepreneurship and contestations in wind energy in India. *Renewable and Sustainable Energy Reviews*, *42*, 999–1011. https://doi.org/10.1016/j.rser.2014.10.039

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., & Schösler, H. (2016). Transition towards circular economy in the food system. *Sustainability (Switzerland)*, *8*(1), 1–14. https://doi.org/10.3390/su8010069

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*(February 2017), 190–201. https://doi.org/10.1016/j.resconrec.2017.10.034

Kamalski, J., & Kirby, A. (2012). Bibliometrics and urban knowledge transfer. *Cities*, *29*, S3–S8. https://doi.org/10.1016/j.cities.2012.06.012

Kanda, W., Geissdoerfer, M., & Hjelm, O. (2021). From circular business models to circular business ecosystems. *Business Strategy and the Environment*, *30*(6), 2814–2829. https://doi.org/doi.org/10.1002/bse.2895

Kay, J., Schoels, M. M., Dörner, T., Emery, P., Kvien, T. K., Smolen, J. S., & Breedveld, F. C. (2018). Consensus-based recommendations for the use of biosimilars to treat rheumatological diseases. *Annals of the Rheumatic Diseases*, *77*(2), 165–174.

Kerdlap, P., Low, J. S. C., & Ramakrishna, S. (2019). Zero waste manufacturing: A framework and review of technology, research, and implementation barriers for enabling a circular economy transition in Singapore. *Resources, Conservation and Recycling*, *151*(September), 104438. https://doi.org/10.1016/j.resconrec.2019.104438

Kern, F., Sharp, H., & Hachmann, S. (2020). Governing the second deep transition towards a circular economy: How rules emerge, align and diffuse. *Environmental Innovation and Societal Transitions*, *37*(June), 171–186. https://doi.org/10.1016/j.eist.2020.08.008

Khan, F., & Ali, Y. (2022). Implementation of the circular supply chain management in the pharmaceutical industry. *Environment, Development and Sustainability*, 1–27. https://doi.org/10.1007/s10668-021-02007-6

Kim, H., Ohnishi, S., Fujii, M., Fujita, T., & Park, H. (2018). Evaluation and allocation of greenhouse gas reductions in industrial symbiosis. *Journal of Industrial Ecology*, *22*(2), 275–287. https://doi.org/10.1111/jiec.12539

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. https://doi.org/10.1016/j.ecolecon.2018.04.028

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular

economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*(September), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Klijn, E.-H., & Koppenjan, J. (2012). Governance network theory: past, present and future. *Policy & Politics*, *40*(4), 587–606.

Klijn, E. H., & Koppenjan, J. (2015). *Governance networks in the public sector*. Routledge.

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*(January), 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*, *143*, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Kortmann, S., & Piller, F. (2016). Open business models and closed-loop value chains: Redefining the firm-consumer relationship. *California Management Review*. https://doi.org/10.1525/cmr.2016.58.3.88

Kravchenko, M., Pigosso, D. C., & McAloone, T. C. (2019). Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: Consolidation of leading sustainability-related performance indicators. *Journal of Cleaner Production*, *241*, 118318. https://doi.org/10.1016/j.jclepro.2019.118318

Krueger, R. A., & Casey, M. A. (2015). Focus groups: A practical guide for applied research 5th Edition. *Focus Groups: A Practical Guide for Applied Research*.

Kulczycka, J., Uberman, R., Dziobek, E. (2020). Industrial Symbiosis for the Circular Economy Implementation in the Raw Materials Sector—The Polish Case. In L. Salomone, R., Cecchin, A., Deutz, P., Raggi, A., Cutaia (Ed.), *Industrial Symbiosis for the Circular Economy*. Springer, Cham. https://doi.org/10.1007/978-3-030-36660-5_5

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing*. sage.

Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. In *Sustainability* (Vol. 8, Issue 1). https://doi.org/10.3390/su8010043

Lijadi, A. A., & van Schalkwyk, G. J. (2015). Online Facebook Focus Group

Research of Hard-to-Reach Participants. *International Journal of Qualitative Methods*, *14*(5), 160940691562138. https://doi.org/10.1177/1609406915621383

Linder, M., Sarasini, S., & van Loon, P. (2017). A Metric for Quantifying Product-Level Circularity. *Journal of Industrial Ecology*, *21*(3), 545–558. https://doi.org/10.1111/jiec.12552

Liu, C., Côté, R. P., & Zhang, K. (2015). Implementing a three-level approach in industrial symbiosis. *Journal of Cleaner Production*, *87*(1), 318–327. https://doi.org/10.1016/j.jclepro.2014.09.067

Llorente-González, L. J., & Vence, X. (2019). Decoupling or "decaffing"? The underlying conceptualization of circular economy in the European union monitoring framework. *Sustainability (Switzerland)*, *11*(18). https://doi.org/10.3390/su11184898

Lombardi, D. R., & Laybourn, P. (2012). Redefining industrial symbiosis: Crossing academic–practitioner boundaries. *Journal of Industrial Ecology*, *16*(1), 28–37. https://doi.org/10.1111/j.1530-9290.2011.00444.x

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. *Annual Review of Environment and Resources*, *42*, 599–626. https://doi.org/10.1146/annurev-environ-102014-021340

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, *42*(3), 237–246. https://doi.org/doi.org/10.1016/j.futures.2009.11.009

Loorbach, D., & Wijsman, K. (2013). Business transition management: Exploring a new role for business in sustainability transitions. *Journal of Cleaner Production*, *45*, 20–28. https://doi.org/10.1016/j.jclepro.2012.11.002

Loorbach, D., Wittmayer, J. M., Shiroyama, H., Fujino, J., & Mizuguchi, S. (2016). *Governance of urban sustainability transitions: European and Asian Experiences*. Springer. https://doi.org/10.1007/978-4-431-55426-4

Low, J. S. C., Tjandra, T. B., Yunus, F., Chung, S. Y., Tan, D. Z. L., Raabe, B., Ting, N. Y., Yeo, Z., Bressan, S., Ramakrishna, S., & Herrmann, C. (2018). A Collaboration Platform for Enabling Industrial Symbiosis: Application of the Database Engine for Waste-to-Resource Matching. *Procedia CIRP*, *69*(May), 849–854. https://doi.org/10.1016/j.procir.2017.11.075

Lyle, J. T. (1996). *Regenerative design for sustainable development*. John Wiley & Sons.

MacLachlan, I. (2013). Kwinana Industrial Area: agglomeration economies and industrial symbiosis on Western Australia's Cockburn Sound. *Australian*

Geographer, *44*(4), 383–400. https://doi.org/10.1080/00049182.2013.852505

Magnusson, T., Andersson, H., & Ottosson, M. (2019). Industrial ecology and the boundaries of the manufacturing firm. *Journal of Industrial Ecology*, *23*(5), 1211–1225. https://doi.org/10.1111/jiec.12864

Malhotra, M. K., & Grover, V. (1998). An assessment of survey research in POM: from constructs to theory. *Journal of Operations Management*, *16*(4), 407–425. https://doi.org/10.1016/S0272-6963(98)00021-7

Mallawaarachchi, H., Sandanayake, Y., Karunasena, G., & Liu, C. (2020). Unveiling the conceptual development of industrial symbiosis: Bibliometric analysis. *Journal of Cleaner Production*, *258*, 120618. https://doi.org/10.1016/j.jclepro.2020.120618

Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., & Aminoff, A. (2018). Do circular economy business models capture intended environmental value propositions? *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2017.10.003

Marconi, M., Gregori, F., Germani, M., Papetti, A., & Favi, C. (2018). An approach to favor industrial symbiosis: the case of waste electrical and electronic equipment. *Procedia Manufacturing*, *21*, 502–509. https://doi.org/10.1016/j.promfg.2018.02.150

Markard, J. (2018). The next phase of the energy transition and its implications for research and policy. *Nature Energy*, *3*(8), 628–633. https://doi.org/10.1038/s41560-018-0171-7

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Martín Gómez, A. M., Aguayo González, F., & Marcos Bárcena, M. (2018). Smart eco-industrial parks: A circular economy implementation based on industrial metabolism. *Resources, Conservation and Recycling*, *135*(August 2017), 58–69. https://doi.org/10.1016/j.resconrec.2017.08.007

Masi, D., Day, S., & Godsell, J. (2017). Supply chain configurations in the circular economy: A systematic literature review. *Sustainability*, *9*(9), 1602. https://doi.org/10.3390/su9091602

Mathews, J. A., & Tan, H. (2011). Progress toward a circular economy in China: The drivers (and inhibitors) of eco-industrial initiative. *Journal of Industrial Ecology*, *15*(3), 435–457. https://doi.org/10.1111/j.1530-9290.2011.00332.x

Mathews, J. A., Tan, H., & Hu, M. C. (2018). Moving to a Circular Economy in China: Transforming Industrial Parks into Eco-industrial Parks. *California*

Management Review, *60*(3), 157–181. https://doi.org/10.1177/0008125617752692

Mattila, T. J., Pakarinen, S., & Sokka, L. (2010). Quantifying the Total Environmental Impacts of an Industrial Symbiosis - a Comparison of Process-, Hybrid and Input-Output Life Cycle Assessment. *Environmental Science & Technology*, *44*(11), 4309–4314. https://doi.org/10.1021/es902673m

Mauthoor, S. (2017). Uncovering industrial symbiosis potentials in a small island developing state: The case study of Mauritius. *Journal of Cleaner Production*, *147*, 506–513. https://doi.org/10.1016/j.jclepro.2017.01.138

Mazur-Wierzbicka, E. (2021). Circular economy: advancement of European Union countries. *Environmental Sciences Europe*, *33*(1). https://doi.org/10.1186/s12302-021-00549-0

McDonough, W., & Braungart, M. (2010). *Cradle to cradle: Remaking the way we make things*. North point press.

Millar, N., McLaughlin, E., & Börger, T. (2019). The Circular Economy: Swings and Roundabouts? *Ecological Economics*, *158*(April 2018), 11–19. https://doi.org/10.1016/j.ecolecon.2018.12.012

Mirata, M. (2004). Experiences from early stages of a national industrial symbiosis programme in the UK: Determinants and coordination challenges. *Journal of Cleaner Production*, *12*(8–10), 967–983. https://doi.org/10.1016/j.jclepro.2004.02.031

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), 993–1002. https://doi.org/10.1016/j.jclepro.2004.12.010

MITECO. (2018). España Circular 2030: estrategia española de economía circular. In *https://www.miteco.gob.es/es/*. https://www.miteco.gob.es/images/es/180206economiacircular_tcm30-440922.pdf

Mohammadi, E., Singh, S. J., & Habib, K. (2021). How big is circular economy potential on Caribbean islands considering e-waste? *Journal of Cleaner Production*, *317*, 128457. https://doi.org/10.1016/j.jclepro.2021.128457

Morioka, S. N., Evans, S., & Carvalho, M. M. de. (2016). Sustainable Business Model Innovation: Exploring Evidences in Sustainability Reporting. *Procedia CIRP*, *40*, 659–667. https://doi.org/10.1016/j.procir.2016.01.151

Mortensen, L., & Kørnøv, L. (2019). Critical factors for industrial symbiosis emergence process. *Journal of Cleaner Production*, *212*, 56–69.

https://doi.org/10.1016/j.jclepro.2018.11.222

Mulrow, J. S., Derrible, S., Ashton, W. S., & Chopra, S. S. (2017). Industrial Symbiosis at the Facility Scale. *Journal of Industrial Ecology*, *21*(3), 559–571. https://doi.org/10.1111/jiec.12592

Music, B. (2019). Urban planning and industrial symbiosis in Slovenia. *IOP Conference Series: Materials Science and Engineering*, *471*(11), 112084. https://doi.org/10.1088/1757-899X/471/11/112084

Nasir, M. H. A., Genovese, A., Acquaye, A. A., Koh, S. C. L., & Yamoah, F. (2017). Comparing linear and circular supply chains: A case study from the construction industry. *International Journal of Production Economics*, *183*, 443–457. https://doi.org/10.1016/j.ijpe.2016.06.008

Nastar, M., Abbas, S., Aponte Rivero, C., Jenkins, S., & Kooy, M. (2018). The emancipatory promise of participatory water governance for the urban poor: Reflections on the transition management approach in the cities of Dodowa, Ghana and Arusha, Tanzania. *African Studies*, *77*(4), 504–525. https://doi.org/10.1080/00020184.2018.1459287

Neves, A., Godina, R., Azevedo, S. G., & Matias, J. C. O. (2019). A comprehensive review of industrial symbiosis. *Journal of Cleaner Production*, *247*, 119113. https://doi.org/10.1016/j.jclepro.2019.119113

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. https://doi.org/10.3390/su11247095

Ng, K. S., & To, L. S. (2020). A systems thinking approach to stimulating and enhancing resource efficiency and circularity in households. *Journal of Cleaner Production*, *275*, 123038. https://doi.org/10.1016/j.jclepro.2020.123038

Nochta, T., & Skelcher, C. (2020). Network governance in low-carbon energy transitions in European cities: A comparative analysis. *Energy Policy*, *138*(January), 111298. https://doi.org/10.1016/j.enpol.2020.111298

Ohnishi, S., Dong, H., Geng, Y., Fujii, M., & Fujita, T. (2017). A comprehensive evaluation on industrial & urban symbiosis by combining MFA, carbon footprint and emergy methods—Case of Kawasaki, Japan. *Ecological Indicators*, *73*, 513–524. https://doi.org/10.1016/j.ecolind.2016.10.016

Ormazabal, M., Prieto-Sandoval, V., Jaca, C., & Santos, J. (2016). An overview of the circular economy among SMEs in the Basque country: A multiple case study. *Journal of Industrial Engineering and Management*, *9*(5), 1047–1058. https://doi.org/hdl.handle.net/10419/188804

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., & Jaca, C. (2018). Circular Economy in Spanish SMEs: Challenges and opportunities. *Journal of Cleaner Production*, *185*, 157–167. https://doi.org/10.1016/j.jclepro.2018.03.031

Pajunen, N., Watkins, G., Husgafvel, R., Heiskanen, K., & Dahl, O. (2013). The challenge to overcome institutional barriers in the development of industrial residue based novel symbiosis products – Experiences from Finnish process industry. *Minerals Engineering*, *46–47*, 144–156. https://doi.org/10.1016/J.MINENG.2013.03.008

Pakarinen, S., Mattila, T., Melanen, M., Nissinen, A., & Sokka, L. (2010). Sustainability and industrial symbiosis—The evolution of a Finnish forest industry complex. *Resources, Conservation and Recycling*, *54*(12), 1393–1404. https://doi.org/10.1016/j.resconrec.2010.05.015

Pan, S.-Y., Du, M. A., Huang, I.-T., Liu, I.-H., Chang, E.-E., & Chiang, P.-C. (2015). Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system: a review. *Journal of Cleaner Production*, *108*, 409–421. https://doi.org/10.1016/j.jclepro.2015.06.124

Panwar, R., & Niesten, E. (2020). Advancing Circular Economy. *Business Strategy and the Environment*, 1–3. https://doi.org/10.1002/bse.2602

Papathanasoglou, A., Panagiotidou, M., Valta, K., & Loizidou, M. (2016). Institutional Barriers and Opportunities for the Implementation of Industrial Symbiosis in Greece. *Environmental Practice*, *18*(4), 253–259. https://doi.org/10.1017/S1466046616000454

Park, H.-S., & Behera, S. K. (2014). Methodological aspects of applying eco-efficiency indicators to industrial symbiosis networks. *Journal of Cleaner Production*, *64*, 478–485. https://doi.org/10.1016/j.jclepro.2013.08.032

Park, J., Duque-Hernández, J., & Díaz-Posada, N. (2018). Facilitating business collaborations for industrial symbiosis: The pilot experience of the sustainable industrial network program in Colombia. *Sustainability (Switzerland)*, *10*(10). https://doi.org/10.3390/su10103637

Park, J. M. (2015). A review of the National Eco-Industrial Park Development Program in Korea: progress and achievements in the first phase, 2005-2010. *Journal of Cleaner Production*, *30*, 1–12. https://doi.org/10.1016/j.jclepro.2015.08.115

Park, J. Y., & Park, H. (2014). Securing a competitive advantage through Industrial Symbiosis Development. *Journal of Industrial Ecology*, *18*(5), 677–683. https://doi.org/10.1111/jiec.12158

Patricio, J., Axelsson, L., Blomé, S., & Rosado, L. (2018). Enabling industrial

symbiosis collaborations between SMEs from a regional perspective. *Journal of Cleaner Production*, *202*, 1120–1130. https://doi.org/10.1016/j.jclepro.2018.07.230

Penn, A. S., Jensen, P. D., Woodward, A., Basson, L., Schiller, F., & Druckman, A. (2014). Sketching a Network Portrait of the Humber Region. *Complexity*, *16*(4), 10–21. https://doi.org/10.1002/cplx.21519

Peterson, H. M., Baker, L. A., Aggarwal, R. M., Boyer, T. H., & Chan, N. I. (2022). A transition management framework to stimulate a circular phosphorus system. *Environment, Development and Sustainability*, *24*(2), 1713–1737. https://doi.org/10.1007/s10668-021-01504-y

Petit-Boix, A., & Leipold, S. (2018). Circular economy in cities: Reviewing how environmental research aligns with local practices. *Journal of Cleaner Production*, *195*, 1270–1281. https://doi.org/10.1016/j.jclepro.2018.05.281

Piet, V., & Hans, D. (2010). *Designing a research project* (Second). Eleven International Publishing.

Pojasek, R. B. (2009). Using leading indicators to drive sustainability performance. *Environmental Quality Management*, *18*(4), 87–93. https://doi.org/10.1002/tqem

Prendeville, S., Cherim, E., & Bocken, N. (2018). Circular Cities: Mapping Six Cities in Transition. *Environmental Innovation and Societal Transitions*, *26*, 171–194. https://doi.org/10.1016/j.eist.2017.03.002

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

Prieto-Sandoval, V., Jaca, C., Santos, J., Baumgartner, R. J., & Ormazabal, M. (2019). Key strategies, resources, and capabilities for implementing circular economy in industrial small and medium enterprises. *Corporate Social Responsibility and Environmental Management*, *26*(6), 1473–1484. https://doi.org/10.1002/csr.1761

Prieto-Sandoval, V., Ormazabal, M., Jaca, C., & Viles, E. (2018). Key elements in assessing circular economy implementation in small and medium-sized enterprises. *Business Strategy and the Environment*, *27*(8), 1525–1534. https://doi.org/10.1002/bse.2210

Prosman, E. J., & Wæhrens, B. V. (2019). Managing waste quality in industrial symbiosis: Insights on how to organize supplier integration. *Journal of Cleaner Production*, *234*, 113–123. https://doi.org/10.1016/j.jclepro.2019.06.169

Pyakurel, P., & Wright, L. (2021). Energy and resources cooperation for greenhouse gases emissions reduction of industrial sector. *Energy & Environment*, *32*(4), 635–647. https://doi.org/10.1177%2F0958305X20949957

Qi, Y., & Wang, W. (2011). Industrial symbiosis management strategy based on flow analysis of industrial solid waste exchange in TEDA, Tianjin—A case study of industrial symbiosis phenomenon in China. *2011 International Conference on Materials for Renewable Energy & Environment*, *1*, 345–349. https://doi.org/10.1109/ICMREE.2011.5930827

Rashid, A., Asif, F. M. A., Krajnik, P., & Nicolescu, C. M. (2013). Resource Conservative Manufacturing: an essential change in business and technology paradigm for sustainable manufacturing. *Journal of Cleaner Production*, *57*, 166–177. https://doi.org/https://doi.org/10.1016/j.jclepro.2013.06.012

Rincon-Moreno, J., Ormazabal, M., Álvarez, M. J., & Jaca, C. (2020). *Shortcomings of Transforming a Local Circular Economy System through Industrial Symbiosis : A Case Study in Spanish SMEs*. https://doi.org/https://doi.org/10.3390/su12208423

Rincón-Moreno, J., Ormazábal, M., Álvarez, M. J., & Jaca, C. (2021). Advancing circular economy performance indicators and their application in Spanish companies. *Journal of Cleaner Production*, *279*. https://doi.org/10.1016/j.jclepro.2020.123605

Rossi, E., Bertassini, A. C., Ferreira, C. dos S., Neves do Amaral, W. A., & Ometto, A. R. (2020). Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases. *Journal of Cleaner Production*, *247*. https://doi.org/10.1016/j.jclepro.2019.119137

Saavedra, Y. M. B., Iritani, D. R., Pavan, A. L. R., & Ometto, A. R. (2018). Theoretical contribution of industrial ecology to circular economy. *Journal of Cleaner Production*, *170*, 1514–1522. https://doi.org/10.1016/j.jclepro.2017.09.260

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A taxonomy of circular economy indicators. *Journal of Cleaner Production*, *207*, 542–559. https://doi.org/10.1016/j.jclepro.2018.10.014

Sánchez Levoso, A., Gasol, C. M., Martínez-Blanco, J., Durany, X. G., Lehmann, M., & Gaya, R. F. (2020). Methodological framework for the implementation of circular economy in urban systems. *Journal of Cleaner Production*, *248*. https://doi.org/10.1016/j.jclepro.2019.119227

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students* (Fifth edit). Pearson education.

Schiller, F., Penn, A., Druckman, A., Basson, L., & Royston, K. (2014). Exploring space, exploiting opportunities: the case for analyzing space in industrial ecology. *Journal of Industrial Ecology*, *18*(6), 792–798. https://doi.org/10.1111/jiec.12140

Schlüter, L., Mortensen, L., & Kørnøv, L. (2020). Industrial symbiosis emergence and network development through reproduction. *Journal of Cleaner Production*, *252*, 119631. https://doi.org/10.1016/j.jclepro.2019.119631

Schot, J., & Kanger, L. (2018). Deep transitions: Emergence, acceleration, stabilization and directionality. *Research Policy*, *47*(6), 1045–1059. https://doi.org/10.1016/j.respol.2018.03.009

Schreck, M., & Wagner, J. (2017). Incentivizing secondary raw material markets for sustainable waste management. *Waste Management*, *67*, 354–359. https://doi.org/10.1016/j.wasman.2017.05.036

Schröder, N. J. S. (2018). The lens of polycentricity: Identifying polycentric governance systems illustrated through examples from the field of water governance. *Environmental Policy and Governance*, *28*(4), 236–251.

Schutt, R. K. (2018). *Investigating the social world: The process and practice of research*. Sage publications.

Scott, J., & Carrington, P. J. (2011). *Handbook of social network analysis*. SAGE publications.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, *16*(15), 1699–1710. https://doi.org/10.1016/j.jclepro.2008.04.020

Shahbazi, S., Wiktorsson, M., Kurdve, M., Jönsson, C., & Bjelkemyr, M. (2016). Material efficiency in manufacturing: Swedish evidence on potential, barriers and strategies. *Journal of Cleaner Production*, *127*, 438–450. https://doi.org/10.1016/j.jclepro.2016.03.143

Sharma, N. K., Govindan, K., Lai, K. K., Chen, W. K., & Kumar, V. (2020). The transition from linear economy to circular economy for sustainability among SMEs: A study on prospects, impediments, and prerequisites. *Business Strategy and the Environment*, *November*, 1–20. https://doi.org/10.1002/bse.2717

Shi, H., Chertow, M., & Song, Y. (2010). Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological

Development Area in China. *Journal of Cleaner Production*, *18*(3), 191–199. https://doi.org/10.1016/j.jclepro.2009.10.002

Shi, L., & Chertow, M. (2017). Organizational boundary change in industrial symbiosis: Revisiting the Guitang Group in China. *Sustainability (Switzerland)*, *9*(7), 1–19. https://doi.org/10.3390/su9071085

Short, S. W., Bocken, N. M. P., Barlow, C. Y., & Chertow, M. R. (2014). From refining sugar to growing tomatoes: Industrial ecology and business model evolution. *Journal of Industrial Ecology*. https://doi.org/10.1111/jiec.12171

Silva, F. C., Shibao, F. Y., Kruglianskas, I., Barbieri, J. C., & Sinisgalli, P. A. A. (2019). Circular economy: analysis of the implementation of practices in the Brazilian network. *Revista de Gestão*, *26*(1), 39–60. https://doi.org/10.1108/rege-03-2018-0044

Simboli, A., Taddeo, R., & Morgante, A. (2014). Analysing the development of Industrial Symbiosis in a motorcycle local industrial network: the role of contextual factors. *Journal of Cleaner Production*, *66*, 372–383. https://doi.org/https://doi.org/10.1016/j.jclepro.2013.11.045

Smol, M., Kulczycka, J., & Avdiushchenko, A. (2017). Circular economy indicators in relation to eco-innovation in European regions. *Clean Technologies and Environmental Policy*, *19*(3), 669–678. https://doi.org/10.1007/s10098-016-1323-8

Smol, M., Marcinek, P., Duda, J., & Szołdrowska, D. (2020). Importance of Sustainable Mineral Resource Management in Implementing the Circular Economy (CE) Model and the European Green Deal Strategy. *Resources*, *9*(6), 1–3. https://doi.org/10.3390/resources9060078

Smol, M., Marcinek, P., & Koda, E. (2021). Drivers and Barriers for a Circular Economy (CE) Implementation in Poland—A Case Study of Raw Materials Recovery Sector. *Energies*, *14*(8), 2219. https://doi.org/10.3390/en14082219

Södergren, K., & Palm, J. (2021). The role of local governments in overcoming barriers to industrial symbiosis. *Cleaner Environmental Systems*, *2*(February), 100014. https://doi.org/10.1016/j.cesys.2021.100014

Sokka, L., Pakarinen, S., & Melanen, M. (2011). Industrial symbiosis contributing to more sustainable energy use – an example from the forest industry in Kymenlaakso, Finland. *Journal of Cleaner Production*, *19*(4), 285–293. https://doi.org/https://doi.org/10.1016/j.jclepro.2009.08.014

Song, M., & Thieme, J. (2009). The role of suppliers in market intelligence gathering for radical and incremental innovation. *Journal of Product Innovation Management*. https://doi.org/10.1111/j.1540-5885.2009.00333.x

Stahel, W. (2010). *The performance economy*. Springer.

T. Vollmeier, A. C. (2015). Case study Spremberg: rdf-fueled CHP plant for a paper mill. *Proceedings of Conferences Promoted by ENEA at Ecomondo in 2012, 2013 and 2014*, 55. http://openarchive.enea.it/bitstream/handle/10840/7105/Experiences-of-Industrial-Symbiosis-in-Italy_Proceedings.pdf?sequence=1

Taddeo, R., Simboli, A., Morgante, A., & Erkman, S. (2017). The Development of Industrial Symbiosis in Existing Contexts. Experiences From Three Italian Clusters. *Ecological Economics*, *139*, 55–67. https://doi.org/10.1016/j.ecolecon.2017.04.006

Teh, B. T., Ho, C. S., Matsuoka, Y., Chau, L. W., & Gomi, K. (2014). Determinant factors of industrial symbiosis: greening Pasir Gudang industrial park. *IOP Conference Series: Earth and Environmental Science*, *18*(1), 12162. https://doi.org/10.1088/1755-1315/18/1/012162

Timmermans, R. W., & Witjes, S. (2016). Circular Business: Collaborate and Circulate; a bookreview. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.06.066

Tukker, A., Sto, E., & Vezzoli, C. (2008). "The governance and practice of change of sustainable consumption and production." Introduction to the ideas and recommendations presented in the articles in this special issue of the journal of cleaner production. *Journal of Cleaner Production*, *16(11)*, 1143–1145. https://doi.org/10.1016/j.jclepro.2007.08.011

Turken, N., & Geda, A. (2020). Supply chain implications of industrial symbiosis: A review and avenues for future research. *Resources, Conservation and Recycling*, *161*(May), 104974. https://doi.org/10.1016/j.resconrec.2020.104974

Valentine, S. V. (2016). Kalundborg Symbiosis: fostering progressive innovation in environmental networks. *Journal of Cleaner Production*, *118*, 65–77. https://doi.org/10.1016/j.jclepro.2016.01.061

van Berkel, R., Fujita, T., Hashimoto, S., & Fujii, M. (2009). Quantitative assessment of urban and industrial symbiosis in Kawasaki, Japan. *Environmental Science & Technology*, *43*(5), 1271–1281. https://doi.org/10.1021/es803319r

Vanhamäki, S., Virtanen, M., Luste, S., & Manskinen, K. (2020). Transition towards a circular economy at a regional level: A case study on closing biological loops. *Resources, Conservation and Recycling*, *156*(January), 104716. https://doi.org/10.1016/j.resconrec.2020.104716

Veldhuizen, C. (2020). Smart Specialisation as a transition management framework: Driving sustainability-focused regional innovation policy? *Research Policy*, *49*(6), 103982. https://doi.org/10.1016/j.respol.2020.103982

Velenturf, A. (2016a). Analysing the governance system for the promotion of industrial symbiosis in the Humber region, UK. *People, Place and Policy Online*, *10*(2), 146–173. https://doi.org/10.3351/ppp.0010.0002.0003

Velenturf, A. (2016b). Promoting industrial symbiosis: empirical observations of low-carbon innovations in the Humber region, UK. *Journal of Cleaner Production*, *128*, 116–130. https://doi.org/10.1016/j.jclepro.2015.06.027

Velenturf, A. (2017). Initiating resource partnerships for industrial symbiosis. *Regional Studies, Regional Science*, *4*(1), 117–124. https://doi.org/10.1080/21681376.2017.1328285

Velenturf, A., & Jensen, P. (2016). Promoting Industrial Symbiosis: Using the Concept of Proximity to Explore Social Network Development. *Journal of Industrial Ecology*, *20*(4), 700–709. https://doi.org/10.1111/jiec.12315

Velenturf, A., & Jopson, J. S. (2019). Making the business case for resource recovery. *Science of the Total Environment*, *648*, 1031–1041. https://doi.org/10.1016/j.scitotenv.2018.08.224

Veleva, V., & Bodkin, G. (2018). Corporate-entrepreneur collaborations to advance a circular economy. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2018.03.196

Vimal, K. E. K. (2019). *An investigation on the impact of industrial symbiosis implementation on organizational performance using analytical hierarchical approach*. https://doi.org/10.1108/BIJ-12-2018-0423

Walls, J. L., & Paquin, R. L. (2015). Organizational Perspectives of Industrial Symbiosis: A Review and Synthesis. *Organization and Environment*, *28*(1), 32–53. https://doi.org/10.1177/1086026615575333

Walmsley, T. G., Ong, B. H. Y., Klemeš, J. J., Tan, R. R., & Varbanov, P. S. (2019). Circular Integration of processes, industries, and economies. *Renewable and Sustainable Energy Reviews*, *107*, 507–515. https://doi.org/10.1016/j.rser.2019.03.039

Walton, M. (2016). Setting the context for using complexity theory in evaluation: boundaries, governance and utilisation. *Evidence & Policy: A Journal of Research, Debate and Practice*, *12*(1), 73–89.

Wang, Q., Deutz, P., & Chen, Y. (2016). Building institutional capacity for industrial symbiosis development: A case study of an industrial symbiosis

coordination network in China. *Journal of Cleaner Production*, *142*, 1571–1582. https://doi.org/10.1016/j.jclepro.2016.11.146

Wang, Q., Tang, H., Yuan, X., Zuo, J., Zhang, J., Gao, Z., & Hong, J. (2018). Investigating vulnerability of ecological industrial symbiosis network based on automatic control theory. *Environmental Science and Pollution Research*, *25*(27), 27321–27333. https://doi.org/10.1007/s11356-018-2753-0

Watkins, G., Husgafvel, R., Pajunen, N., Dahl, O., & Heiskanen, K. (2013). Overcoming institutional barriers in the development of novel process industry residue based symbiosis products–Case study at the EU level. *Minerals Engineering*, *41*, 31–40. https://doi.org/10.1016/j.mineng.2012.10.003

Winans, K., Kendall, A., & Deng, H. (2017). The history and current applications of the circular economy concept. *Renewable and Sustainable Energy Reviews*, *68*(September 2016), 825–833. https://doi.org/10.1016/j.rser.2016.09.123

Wittmayer, J. M., & Loorbach, D. (2016). *Governing Transitions in Cities: Fostering Alternative Ideas, Practices, and Social Relations Through Transition Management*. 13–32. https://doi.org/10.1007/978-4-431-55426-4_2

Xiang, P., & Yuan, T. (2019). A collaboration-driven mode for improving sustainable cooperation in smart industrial parks. *Resources, Conservation and Recycling*, *141*(March 2018), 273–283. https://doi.org/10.1016/j.resconrec.2018.10.037

Xue, Y., Bressers, H., & Wen, Z. (2019). A Massive Urban Symbiosis: A Preliminary Review of the Urban Mining Pilot Base Programme in China. *Towards Zero Waste*, 121–143. https://doi.org/10.1007/978-3-319-92931-6_7

Yazan, D. M., Romano, V. A., & Albino, V. (2016). The design of industrial symbiosis: an input–output approach. *Journal of Cleaner Production*, *129*, 537–547. https://doi.org/10.1016/j.jclepro.2016.03.160

Yin, R. K. (2003). Case study research design and methods third edition. *Applied Social Research Methods Series*, *5*.

Yin, R. K. (2015). *Qualitative research from start to finish*. Guilford publications.

Yu, B., Li, X., Shi, L., & Qian, Y. (2015). Quantifying CO2 emission reduction from industrial symbiosis in integrated steel mills in China. *Journal of Cleaner Production*, *103*, 801–810. https://doi.org/https://doi.org/10.1016/j.jclepro.2014.08.015

Yu, C., Dijkema, G. P. J., & de Jong, M. (2015). What Makes Eco-Transformation of Industrial Parks Take Off in China? *Journal of Industrial Ecology*, *19*(3), 441–456. https://doi.org/doi.org/10.1111/jiec.12185

Yu, F., Han, F., & Cui, Z. (2015a). Assessment of life cycle environmental benefits of an industrial symbiosis cluster in China. *Environmental Science and Pollution Research*, *22*(7), 5511–5518. https://doi.org/10.1007/s11356-014-3712-z

Yu, F., Han, F., & Cui, Z. (2015b). Evolution of industrial symbiosis in an eco-industrial park in China. *Journal of Cleaner Production*, *87*(C), 339–347. https://doi.org/10.1016/j.jclepro.2014.10.058

Yu, Y., 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*, 126083. https://doi.org/10.1016/j.jclepro.2021.126083

Yuan, Evans, S., Wen, Z., & Ma, M. (2019). The influence of policy on industrial symbiosis from the Firm's perspective: A framework. *Journal of Cleaner Production*, *213*, 1172–1187. https://doi.org/10.1016/j.jclepro.2018.12.176

Zhang, X., & Chai, L. (2019). Structural features and evolutionary mechanisms of industrial symbiosis networks: Comparable analyses of two different cases. *Journal of Cleaner Production*, *213*, 528–539. https://doi.org/10.1016/j.jclepro.2018.12.173

Zhang, Y., Zheng, H., Chen, B., & Yang, N. (2013). Social network analysis and network connectedness analysis for industrial symbiotic systems: Model development and case study. *Frontiers of Earth Science*, *7*(2), 169–181. https://doi.org/10.1007/s11707-012-0349-4

Zhang, Y., Zheng, H., & Fath, B. D. (2015). Ecological network analysis of an industrial symbiosis system: A case study of the Shandong Lubei eco-industrial park. *Ecological Modelling*, *306*, 174–184. https://doi.org/https://doi.org/10.1016/j.ecolmodel.2014.05.005

Zhe, L., Yong, G., Hung-Suck, P., Huijuan, D., Liang, D., & Tsuyoshi, F. (2016). An emergy-based hybrid method for assessing industrial symbiosis of an industrial park. *Journal of Cleaner Production*, *114*, 132–140. https://doi.org/10.1016/j.jclepro.2015.04.132

Zhu, Q., Geng, Y., & Lai, K. (2011). Environmental supply chain cooperation and its effect on the circular economy practice-performance relationship among Chinese manufacturers. *Journal of Industrial Ecology*, *15*(3), 405–419.

Zhu, Q., Geng, Y., Sarkis, J., & Lai, K. H. (2014). Barriers to promoting eco-lndustrial parks development in China: Perspectives from senior officials at National Industrial Parks. *Journal of Industrial Ecology*, *19*(3), 457–467. https://doi.org/10.1111/jiec.12176

A

APPENDIX A: MATERIAL USED IN THE TRANSITION ARENA PROCESS

This appendix presents the data and questions used in the semi-structured interviews conducted in the development phase of this research.

DESCRIPTIVE ANALYSIS

Figure 21. Location of industrial parks

	C1-T	C2-T	C3-T	C4-T	C5-T	C6	C7-T	C8
	Poligono	nombre empresa	cif	activo	contenedor	cantidad	creado	metros de oficina
1	POLIGONO 27	GAES, S.A.	A20030930	Y	Contenedor Inerte y Material reciclable (360L)	1	2019-06-21 12:10:37.685	*
2	POLIGONO 27	BSH ELECTRODOMESTICOS ESPAÑA, S.A.	A28093550	Y	Contenedor Inerte y Material reciclable (1300L)	1	2019-06-19 09:02:02.324	*

	C1-D	C2-T	C3-T	C4-T	C5-T	C6-T	C7	C8	C9
	fecharegistro	poligono	codigo empresa	empresa	actuacion	dato			
1	7/2/2019 0:00	POLIGONO 27	PC.00204	SUGREM	Felicion. Servicio Film	Missing			
2	7/2/2019 0:00	POLIGONO 27	PC.00220	RUTONILAN, S.L.	Felicion. Servicio Film	Missing			

Figure 22. Excel spreadsheet with waste data

INDUSTRIAL PARK SYNERGIES

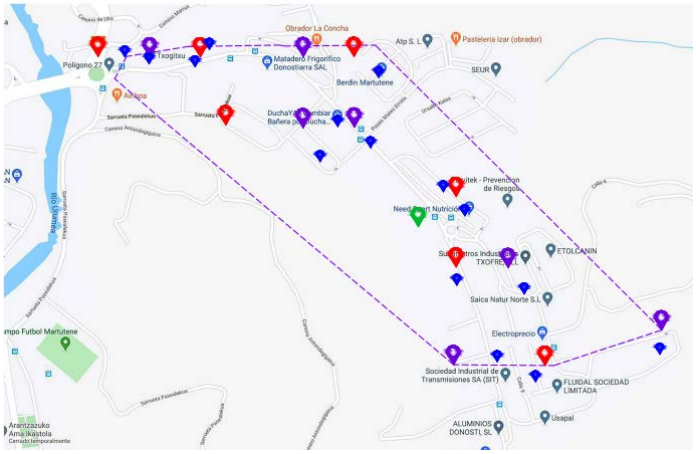


Figure 23. "Polígono 27" industrial park

QUESTIONS

Sección 1: Entrevistado

1. Aproximadamente, ¿en cuántos proyectos de simbiosis o economía circular ha participado?

2, ¿Cuál ha sido su rol principal?

3. ¿Durante cuánto tiempo lleva en contacto con este tipo de proyectos?

Sección 2: Proyectos de Simbiosis.

Esta sección de preguntas está dirigida a conocer el proceso de desarrollo y ejecución de los proyectos de simbiosis industrial y los diferentes factores internos que influyen en la creación de los mismos.

4. ¿Cuál es el objetivo del/los proyectos que desarrolla? ¿Qué directrices e iniciativas se tienen en cuenta a la hora de plantear un proyecto?

5. ¿Cuáles son los pasos para crear un proyecto y la generación de las redes de simbiosis industrial? En general.

6. ¿Cómo se formó el consorcio del proyecto? ¿Existía algún interés previo, o fue algo que no se había planeado y a partir de un promotor, o proyecto a algo externo, surgió? En ese caso ¿cómo se contactó a las empresas participantes?

7. ¿Qué tipo de empresas son las que generalmente muestran más interés? ¿Por qué motivo considera que es así?

8. En los proyectos en general, ¿Qué elementos (organismos públicos, ayudas, interés de empresas) fueron claves para el desarrollo del proyecto?

9. ¿Qué proyectos surgen con más facilidad? ¿Qué características tienen? ¿Existe algún residuo/material el cual sea más llamativo para llevar a cabo?

10. En cuanto a los residuos, ¿qué parte de estos se recupera? ¿qué ocurre con lo "no recuperable"?

11. De media, ¿qué porcentaje de las intercambios o aprovechamientos de los residuos y recursos se pueden realizar directamente y qué porcentaje de esos recursos necesita un tratamiento para su aprovechamiento?

12. ¿Qué tipo de residuos/recursos son los que no acaban de concretarse en proyectos de simbiosis, a pesar de su potencial? ¿Por qué?

13. ¿Qué beneficios o logros destacaría de la simbiosis?

14. En el caso de haber participado en algún proyecto donde entidades internacionales participen ¿qué beneficios nota al momento de la ejecución del proyecto?

Sección 3: Agentes

Como complementario a la sección anterior, esta sección profundiza en los agentes participantes del proyecto y la relevancia de estos dentro de los proyectos.

15. ¿Qué agentes se tienen que involucrar para que se lleva a cabo la simbiosis industrial entre empresas?

16. ¿Qué papel juegan estos agentes?

17. ¿Cuáles son los más importantes?

18. ¿Qué elementos (organismo público, ayudas, interés de las empresas,) son clave para el desarrollo de la simbiosis?

Sección 4: Contexto y futuro de economía circular en España

19. ¿Cuáles son las limitaciones que identifica al momento de plantear un proceso?

20. ¿Cuáles son los factores críticos para concretar un proyecto, más allá del intercambio de recursos?

21. Cuando finaliza un proyecto ¿qué factores y/o indicadores se tienen en cuenta para determinar el éxito del proyecto? ¿qué podría impulsarlo a continuar el proyecto?

22. ¿Cuáles son los retos qué se vienen para el futuro de la economía circular y simbiosis industrial dentro de la comunidad autónoma? ¿Qué influencia puede llegar a tener las estrategias de economía circular de su comunidad para la generación de nuevos proyectos? ¿Considera necesario algún cambio en la legislación actual para facilitar la simbiosis?

23. ¿Conoce las iniciativas y leyes relativas a la simbiosis industrial a nivel local y nacional? ¿Y a nivel europeo? Si es así, le parecen suficientes, ¿qué otros instrumentos propondrían?

24. ¿Qué herramientas (plataformas web, metodologías, instrumentos de análisis, instrumentos técnicos) considera que pueden ayudar en el desarrollo de un proyecto de simbiosis?

B

APPENDIX B: MATERIAL USED IN THE FOCUS GROUP

This appendix presents the agenda and material used in the activities conducted in the focus group in this research's development phase.

FOCUS GROUP PRESENTATION SCRIPT

10:00 – Entrar Mentxu, Marta, María Jesús, Flor y John a Zoom. Renombrar a John. Chequear pantallas compartidas John, audios portátiles, activar los permisos para grabar de Mentxu, Marta, M. Jesús y Flor.

10:30 - Inicio de la jornada en Zoom. John renombra los usuarios según el número de grupo asignado a medida que los participantes vayan ingresando

10:35 – No empezar hasta que John tenga renombrados a los participantes. Palabras de apertura de Carmen Jaca.

10:40 – John comparte pantalla y muestra la presentación PPT (compartir en pantalla desktop 2). Dar clic al logo Tecnun para reproducir video https://youtu.be/2LBZBTlu58s **(asegurarse que la opción audio del portátil esté habilitada).**

10:44 – John hace la introducción al workshop en la presentación PowerPoint **hasta las facilitadoras.** Ustedes escribirán a través del chat de zoom cuáles serían las estrategias que elegirían para lograr una transformación hacía la economía circular en este tipo de gestión.

10:48 – John abre las salas de zoom con las respectivas facilitadoras

10:50 – Cada facilitadora empieza a grabar.

-La facilitadora comparte pantalla del Miro y hace la presentación personal, lee de nuevo el objetivo de la jornada que se encuentra a mano derecha del tablero llamado 'presentación del grupo'. La facilitadora deja que los demás participantes se presenten con **Nombre y empresa**. La facilitadora comenta que es necesario designar un representante del grupo para exponer las ideas

10:55 Una vez terminada la presentación, la facilitadora comparte pantalla en zoom, mostrando el miro y dice lo siguiente:

Pensar en estrategias encaminadas a crear cambios en estructuras establecidas como instituciones, regulaciones, finanzas o estructuras físicas que serían relevantes para

implementar en el corto y mediano plazo. Anotarlas en los tres tipos de gestiones propuestos en el miro:

Los participantes escribirán a través del chat de zoom cuáles serían las estrategias que elegirían para lograr una transformación hacía la economía circular en este tipo de gestión. Preguntarles cuando den una idea, a qué se refieren con ella. Ha de pedirles que hagan lo mismo para los dos siguientes tipos de gestión. Importante: no invertir más de 10 minutos por gestión.

11:10 La facilitadora les pedirá a los participantes que expliquen brevemente las ideas y eliminarán duplicados. Una vez una estrategia está acordada, la facilitadora la duplicará (control c, control v) y la dejará en la parte de abajo de su respectivo tablero para que John las recoja y las ubique en la zona de votación

11:25. John llamará a todos los participantes a la plenaria de zoom y pone la pantalla compartida para mostrar la presentación PPT con la dinámica de actividad 2, les explicará de que trata, John comentará en términos generales lo que se ha visto. Luego los invitará a que den 1 voto (4 minutos) por las tres estrategias que crean que son más factibles de conseguir en el corto y mediano plazo y les comparte el enlace para votar.

Una vez terminada la votación, John copiara las tres opciones más votadas por gestión y las dejará abajo del tablero para que Marta recoja y copie las 3 mejores estrategias de la gestión de residuos. Florencia hará lo mismo, pero con la gestión recursos y los pasarán a cada uno de los 4 tableros de la actividad 3.

Nota: Si no pueden votar las facilitadoras indicarán que refresquen la pantalla. Han de decirles que una vez terminen, deben darle al botón "done" para cerrar la votación. Se repetirá lo mismo para cada tipo de gestión. **LAS FACILITADORAS NO VOTAN**

11:37 Muestra la PPT en la actividad 3 y explicar la dinámica. Se envían a los participantes de nuevo a las salas zoom y se empieza con la última actividad.

Las facilitadoras activarán de nuevo la grabación

La facilitadora compartirá de nuevo pantalla en zoom mostrando el tablero de Miro. Se les pide a los participantes que, sobre cada una de las nueve estrategias, comenten qué tipo de rol jugaría ese actor. La facilitadora ira escribiendo sobre el recuadro de cada rol lo que se va comentando

12:15 John trae a todos a la plenaria y hace una breve conclusión de lo que se ha recogido en la jornada, anunciando que recibirán un informe de estos resultados. Se despide y cierra el zoom

La facilitadora deberá guardar la grabación y anotar para la reunión posterior los participantes con mejores ideas.

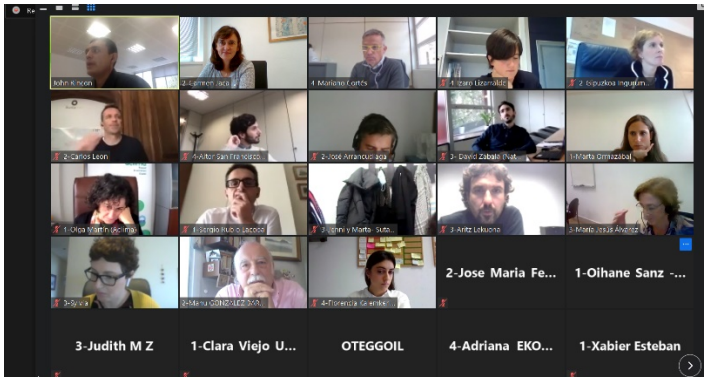


Figure 24. Focus group participants

FOCUS GROUP INTERACTION

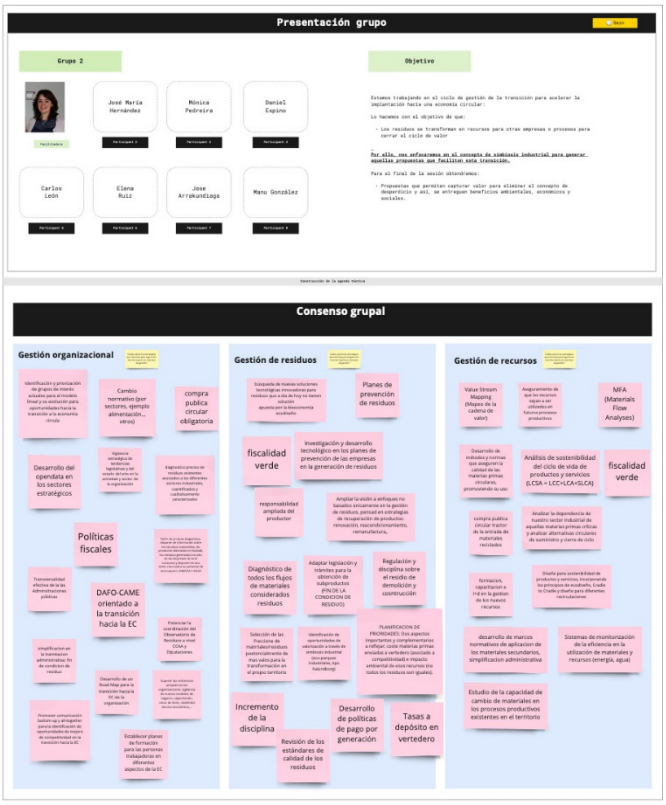
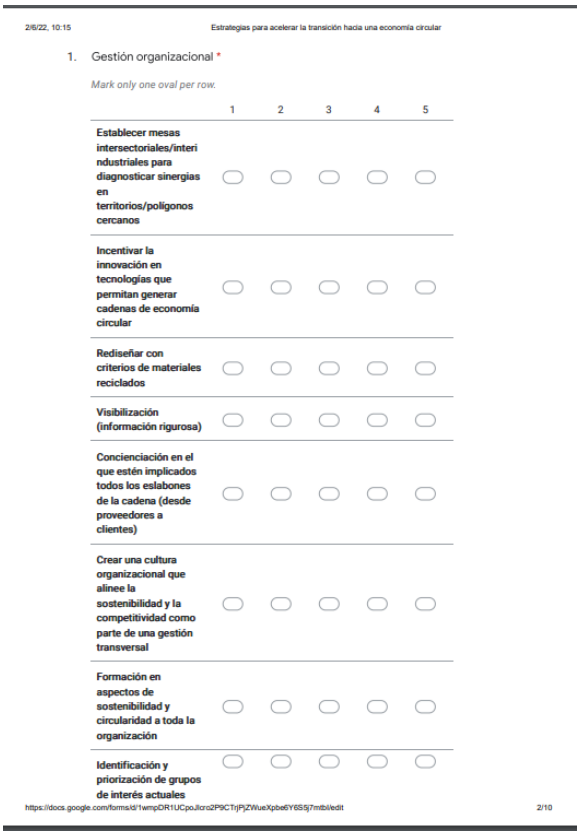


Figure 25. Strategies proposed in the breakout rooms

Figure 26. Strategies discussed by the stakeholders in the plenary session.



2/6/22, 10:15 Estrategias para acelerar la transición hacia una economía circular

1. Gestión organizacional *

Mark only one oval per row.

	1	2	3	4	5
Establecer mesas intersectoriales/interindustriales para diagnosticar sinergias en territorios/poligonos cercanos					
Incentivar la innovación en tecnologías que permitan generar cadenas de economía circular					
Rediseñar con criterios de materiales reciclados					
Visibilización (información rigurosa)					
Concienciación en el que estén implicados todos los eslabones de la cadena (desde proveedores a clientes)					
Crear una cultura organizacional que alinee la sostenibilidad y la competitividad como parte de una gestión transversal					
Formación en aspectos de sostenibilidad y circularidad a toda la organización					
Identificación y priorización de grupos de interés actuales					

https://docs.google.com/forms/d/1wmpDR1UCpoJlcro2P9CTrjPjZWueXpbe6Y6S5j7mbl/edit 2/10

Figure 27. Survey to rank strategies' relevance

C

APPENDIX C: MATERIAL USED IN THE TRANSITION EXPERIMENT PHASE

This appendix presents the data and questions used in the semi-structured interviews conducted in the development phase of this research.

Protocolo de entrevista

Introducción

- ¿Para qué organización trabajas?
- ¿Cuál es el propósito de su organización?
- ¿Cuál es su rol en la organización?

Economía circular en general

- ¿Cómo definiría la economía circular? ¿Se considera un tema importante en su organización?
- ¿Está involucrado en actividades relacionadas con la economía circular en su organización?
- ¿Cuál es el potencial de implementar la economía circular para su organización?

Incentivos

- ¿Ha recibido o creado algún tipo de tipo de beneficio económico o ayuda, tales como premios, subvenciones, asesoramiento, tutoría o acompañamiento de expertos por participar en actividades economía circular?

Sí: ¿Qué tipo de incentivo ha recibido o promovido?

- ¿Ha influido en alguna política que encarezca el envío de residuos a vertedero?
- ¿Ha pagado algún tipo de tarifa adicional que incremente los costes de enviar residuos al vertedero?
- ¿Ha promovido o creado mecanismos para la compra de bienes o servicios con criterios circulares?

- Sí: ¿Qué criterios ha usado para la compra de bienes o servicios circulares? / ¿Qué tipo de compras o servicios circulares han adquirido?
- ¿Ha creado algún indicador o dato para conocer el impacto de esta medida?

Colaboración

- ¿Ha utilizado o promovido canales de colaboración para la reutilización o reciclaje de sus residuos?

Sí: ¿Con quiénes se ha colaborado? / ¿Cómo se ha colaborado?

No: ¿Por qué no se ha dado esta colaboración? o si se ha dado algún acercamiento, ¿por qué no se ha concretado?

- ¿Ha creado algún indicador o dato para conocer el impacto de esta medida?

Caracterización

- ¿Ha creado iniciativas que le permitan identificar, caracterizar o seleccionar sus excedentes o residuos para su recuperación o reciclaje?

Sí: ¿Cuáles han sido los principales resultados de este análisis? / ¿Ha promovido o implementado alguna iniciativa como resultado de este diagnóstico?

- ¿Ha creado algún indicador o dato para conocer el impacto de esta medida?

Investigación, desarrollo e innovación

- ¿Ha impulsado o creado iniciativas que permitan generar innovaciones tecnológicas relacionadas con la economía circular?
- ¿Ha recibido, participado o creado programas de formación en actividades relacionadas con la economía circular?

Recirculación

- Para sus productos o servicios, ¿existe algún tipo de procedimiento o mecanismo para recuperar o gestionar los productos en su fin de vida?

Sí: ¿Qué tipo de mecanismos? / ¿Cómo han sido promovidas estas iniciativas?

- ¿Ha incorporado o promovido principios de eco-diseño para reducir los impactos ambientales asociados a la fabricación, uso o residuos desde la fuente y promover el reúso del producto al final de su ciclo de vida?

Sí: ¿En qué medida lo ha logrado? / ¿Qué herramientas ha utilizado para impulsar esta iniciativa?

- ¿Ha creado iniciativas enfocadas en la restauración, reacondicionamiento, remanufactura de productos?

Sí: ¿Ha creado alguna línea de negocio nueva basada en este enfoque? / ¿Ha promovido incentivos para las organizaciones directamente involucradas en este enfoque?

- ¿Ha creado algún indicador o dato para conocer el impacto de esta medida?

D

APPENDIX D: MATERIAL USED IN THE TRANSITION MONITORING PHASE

This appendix presents the activities conducted in the monitoring phase in the development phase of this research.

Assessment of indicators

3/12/2018 Herramienta de diagnóstico del estado de la economía circular en empresas

11. **11. Por favor, califique de 1 a 7 el cumplimiento de la legislación ambiental por parte de sus proveedores** *
Donde 1 es la menor calificación y 7 la más alta
Mark only one oval.

	1	2	3	4	5	6	7	
No la cumplen	◯	◯	◯	◯	◯	◯	◯	Cumplen por encima de las exigencias legales

12. **12. ¿Considera que los materiales utilizados en la producción son biodegradables?** *
Marca solo un óvalo
Mark only one oval.

	1	2	3	4	5	6	7	
Nada biodegradables	◯	◯	◯	◯	◯	◯	◯	100% biodegradables

13. **13. ¿Considera que los materiales NO biodegradables utilizados en la producción se podrían re-utilizar, reciclar o re-manufacturar?** *
Marca solo un óvalo
Mark only one oval.

	1	2	3	4	5	6	7	
Nada	◯	◯	◯	◯	◯	◯	◯	100% recirculables

14. **14. Por favor, indicar la cantidad (kg) de material consumido en la empresa en el año 2017** *
Ejemplos de materiales: vidrio, plástico, papel-cartón, aluminio, otros.

15. **15. ¿Cuántos kg de este material consumido son de origen reciclado en el año 2017?** *
Ejemplos de materiales: vidrio, plástico, papel-cartón, aluminio, otros.

16. **16. Por favor, indicar el gasto total en compras del año 2017 (€). No incluir inversiones ni consumo de agua y energía** *

https://docs.google.com/forms/d/1B6zl35wsskoUymOeNtNvML_baZXGTi20EWVcqVnA2WE/edit 4/10

Figure 28. Survey sent to industries.

E

APPENDIX E: MATERIAL USED IN THE CASE STUDY IN THE HUMBER REGION

This appendix presents the activities conducted in the case studies in the refinement phase of this research.

INVITATION TO PARTICIPATE TO STAKEHOLDERS IN THE HUMBER REGION

Participant information sheet

Study title: Research on the transition towards a circular economy in the Humber region industrial context.

We want to invite you to take part in an academic study. Before you decide, you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take time to decide whether to take part.

I am a visiting PhD researcher at the University of Leeds, working with Dr Anne Velenturf under the Transforming Foundation Industries Research and Innovation Hub "TransFIRe". I am investigating the processes that can be employed by stakeholders interested in exploring a transition towards a circular economy model that uses resources efficiently.

My study seeks to identify the processes that can improve the management capabilities of a waste-to-resource exchange (e.g., industrial symbiosis) as part of implementing a circular economy (Figure 29). A transition framework for the circular economy was developed in the Basque Country, and this study seeks to analyse its transferability to other regions.

Figure 29. Circular economy model

At this research stage, I seek to talk to people whose personal or professional position has given them first-hand knowledge of the strategies used to operationalise industrial symbiosis in the Humber region and have a crucial

source of empirical validation of the proposed transition framework. This validation aims to understand the factors, criteria and prioritisations that would help to understand the transition towards a circular economy through industrial symbiosis (Figure 30).

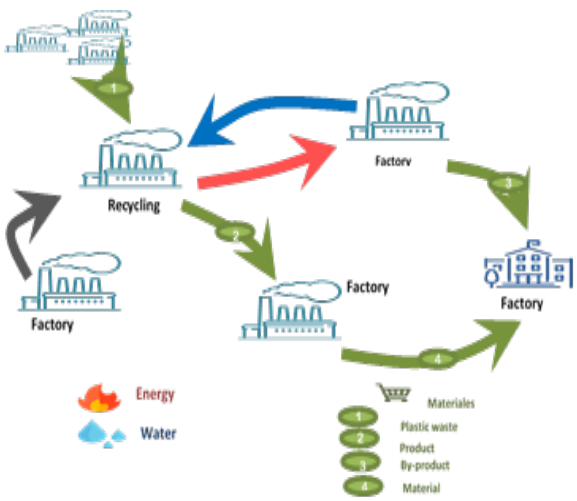


Figure 30. Industrial symbiosis

What is the purpose of the research?

My study is conducted for academic purposes and is part of my PhD thesis on the transition toward a circular economy. It aims to identify how waste-to-resource exchanges supported by multiple stakeholders could reduce resource depletion by using a sustainability transition methodology to facilitate circular economy implementation. I am conducting interviews and a Delphi study (explained below) to support this work.

Why have I been invited to take part?

You have been invited to participate because my research has suggested that you know the factors influencing the potential transition towards a circular economy. Another participant may have also suggested you.

Do I have to take part?

It is up to you to decide. We will describe the study and go through this information sheet, and we will then ask you to sign a consent form to show that you have agreed to participate.

What do I have to do/ what will happen to me if I agree to participate?

Interviews

You will participate in a pre-arranged, recorded interview that will last approximately an hour. Interviews will be conducted remotely using video conferencing technology (for example, Microsoft Teams or Skype).

I will interview you.

In the interview, you will be asked about your background, factors, strategic development, operational activities, business case, and evaluation for collective learning to implement an industrial symbiosis.

After collecting the interviews, I will analyse them, looking for the main topics and themes discussed.

How will you use this information?

I will use this information for academic publications (journals/ books) and semi-academic publications (project reports, blog posts), which you might share as supplementary material. No other use will be made of the data provided by you without your prior emailed consent.

Will my taking part in this project be kept confidential? / What will happen to my data?

Interview

The interview will be recorded and transcribed. Digital copies of the audio recording and the transcription will be kept on a protected drive accessible only by myself at the University of Leeds.

Your interview will be anonymised, and you will be assigned a pseudonym.

Your consent form and identifiable information linked to the pseudonym will be kept separately. Any identifiable information (place of residence or business, or work) will be removed from the transcription.

The anonymised transcription of your interview will only be used for the current study. All participant contact details will be deleted at the end of the study.

Your name will not appear in any reports or publications, and your affiliation will also stay confidential.

The anonymised data underpinning the published works might be shared as supplementary material.

Can I withdraw from the study?

If you want to withdraw from the study, please inform us within a week of the interview/survey. After a week, we will have begun analysis, and removing your data from our dataset may no longer be possible.

What are the possible disadvantages, risks, and benefits of taking part?

There is no foreseeable risk, disadvantage, or direct benefit associated with participating in this research. However, I hope this work will help me understand how to achieve a circular economy transition.

Who is organising or sponsoring the research?

The University of Leeds sponsors this research in the Humber region. My PhD is sponsored by the University of Navarra and the Provincial Council of Gipuzkoa (Spain).

Contact details

To take part or to find out more please contact:

PhD (c) John Rincon, University of Leeds, School of Civil Engineering

Email address: cnjarm@leeds.ac.uk

QUESTIONS

Introduction

- Which organisation do you work for?
- What is your role in the organisation?
- Are there any ways your organisation is engaged in industrial symbiosis-related activities?

General questions

According to you:

- Is industrial symbiosis considered an essential topic in your organisation?
- Are there any ways in which your organisation is promoting industrial symbiosis?
- What is the potential of implementing industrial symbiosis for your organisation?

Industrial symbiosis (agenda)

According to you:

- Are there any actions/commitments at the strategic level (e.g., policies, regulations, plans, programmes) related to industrial symbiosis for your organisation?
- Have the strategies initially used for industrial symbioses, such as the National Industrial Symbiosis Programme, changed in 2012 in the Humber region?
- Do institutions' role today would help increase the adoption of industrial symbiosis?
- Do you think other types of organisations should facilitate the implementation of industrial symbiosis, and which ones?
- Do you consider that the current stakeholders should participate in creating industrial symbiosis policies, regulations, plans and programs in the region?

Industrial symbiosis (experiments)

According to you:

- What are the primary resources streams (in material terms such as water, waste, paper, and plastic) and energy sources that your organisation is currently managing/working on to advance industrial symbiosis?
- What actions or commitments should have been taken to improve the implementation of industrial symbiosis in the Humber region?
- What are the practices/activities that you think need to be considered in the future (e.g., waste, energy, transport, water, paper, plastic, sharing, etc.) to incorporate industrial symbiosis within your organisation?
- Has technological development lasted over time because of learning to carry out industrial symbiosis?
- What have been the most critical stakeholders in developing industrial symbiosis within your organisation?

PUBLICATIONS

This chapter includes the publications achieved as a result of this research. First, papers directly related to the results of this PhD thesis are presented. Secondly, other papers of the author of this PhD thesis are listed. The publications are classified by the different types of publications, namely journal and conference publications.

P1. PUBLICATIONS RELATED TO THE THESIS

P1.1 SCIENTIFIC JOURNAL PUBLICATIONS

Authors: Rincón-Moreno J, Ormazabal M, Alvarez M.J, Jaca C

Title: Shortcomings of Transforming a Local Circular Economy System through Industrial Symbiosis: A Case Study in Spanish SMEs.

Journal: Sustainability

Year: 2020 **Volume**: 12(20) **Pages**: 1-18

Indexed in: JCR (Q2)

Authors: Rincon-Moreno J, Ormazábal M, Jaca C.

Title: Stakeholder perspectives in transitioning to a local circular economy: a case study in Spain.

Journal: Circular economy and sustainability

Year: 2021 **Volume**: NA **Pages**: 1-19

Indexed in: Google Scholar

Authors: Rincón-Moreno J, Ormazabal M, Alvarez M.J, Jaca C

Title: Advancing Circular Economy performance indicators and their application in Spanish companies

Journal: Cleaner production

Year: 2021 **Volume**: 279 **Pages**: 123605

Indexed in: JCR (Q1)

Authors: Rincón-Moreno J, Ormazabal M, Alvarez M.J, Jaca C

Title: Industrial symbiosis strategies for transitioning towards a circular economy: perspectives from Spanish stakeholders.

Journal: Sustainable development

Year: 2022 **Status**: Minor revision

Authors: Rincón-Moreno J., Orjuela-Garzón W., Jaca C, Ormazábal M.

Title: Insights for a transition towards a circular economy through industrial symbiosis.

Journal: SAGE Open

Year: 2022 **Status**: Minor revision

P1.2 CONFERENCE PUBLICATIONS

Authors: Rincón-Moreno, John, Jaca, Carmen, Álvarez, María Jesús, Ugartemendia, Pedro, Ormazabal, Marta

Title: Analysis of industrial waste management regulation to drive resource management in a circular economy: a case study in Spain

Conference: 26th International Sustainable Development Research Society

Place and date: Online, 2020, July 14-17

Authors: Rincón-Moreno J, Ormazabal M, Alvarez M.J, Jaca C.

Title: Circular economy implementation strategies towards circular economy operationalization: transition perspectives from the meso-level in Spain.

Conference: 27th International Sustainable Development Research Society

Place and date: Online, 2021, July 13-15

Authors: Rincón-Moreno J, Velenturf A, Jaca C, Ormazabal M

Title: A transition methodology framework towards a circular economy in industrial contexts: reflections on the Humber Region scenario

Conference: 8th International Conference on Building Resilience

Place and date Stockholm, Sweden, 2022, June 15-17

P2. OTHER PUBLICATIONS

P2.1 CONFERENCE PUBLICATIONS

Authors: Jaca C, Rincon J, Barrenechea P, Ormazabal M

Title: Promoting Circular Economy Through Industrial Symbiosis Platforms: A Comparative Analysis.

Conference: Conference on Industrial and Operations Management

Place and date: Asturias, Spain, 2019, July 11 & 12

Authors: M. Ormazabal, F. García, C. Jaca, J Rincón-Moreno, and M. J. Alvarez

Title: Fostering industrial symbiosis. Potential drivers and barriers.

Conference: 15th International Conference on Industrial Engineering and Industrial Management.

Place and date: Online, 2021, July 8 & 9
