GOVERNING THE TRANSITION TO A CIRCULAR ECONOMY

RACHEL GREER

GOVERNING THE TRANSITION TO A CIRCULAR ECONOMY

Rachel Greer

This research received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 730254 within the Sustainable Urbanization Global Initiative (SUGI) from JPI Urban Europe. Rachel L. Greer receives national funding through the Dutch Research Council (project number 438-17-405). These funders had no involvement in the design, data handling, or writing of this publication.

Provided by thesis specialist Ridderprint, ridderprint.nl

Printing: Ridderprint
ISBN: 978-94-6458-328-1
Coverdesign & layout: Marilou Maes, persoonlijkproefschrift.nl

Governing the Transition to a Circular Economy

Key dynamics, paradoxes, and implications for strategizing

Het besturen van de transitie naar een circulaire economie

Centrale dynamiek, paradoxen en implicaties voor strategieën

Thesis

to obtain the degree of Doctor from the
Erasmus University Rotterdam
by command of the
rector magnificus

Prof.dr. A.L. Bredenoord

and in accordance with the decision of the Doctorate Board.
The public defense shall be held on
Thursday, 23 June 2022, at 13.00 hrs

by

Rachel Lynn Greer

born in St. Louis, Missouri,
United States of America

Erasmus University Rotterdam

Doctoral Committee

Promotor:

Prof.dr. D.A. Loorbach

Other members:

Prof.dr. W.M. de Jong

Prof.dr. N. Bocken

Dr. S.P. Kennedy

Co-promotor:

Dr. T. von Wirth

ACKNOWLEDGEMENTS

I am deeply grateful to many people for their positive impact on the development of my thesis and on my PhD journey – without whom this dissertation may have never come to be. I am happy to thank these extra-special colleagues, family, and friends explicitly here:

To my promotor Derk Loorbach and co-promotor Timo von Wirth for helping shape me into the scientist I am, holding me to high standards (while also encouraging me to reign in my often unrealistic standards for myself), and supporting me with feedback on my writings and publications throughout my PhD. I give a big thank you to both for challenging me in my research while also encouraging me to explore. I am thankful for Derk's vocalized predilection for always pushing things forward (when research and writing can go on infinitely) and for his down-to-earth, horizontal management style. I am thankful for Timo's ability to structure the sometimes-jumbled writing and conceptualizations from my head. Further, I am thankful to both of them for seeing something special in me, when I was merely an applicant among many vying for this position.

To all the DRIFTers who together make the organization so special, and to DRIFT as an organization more generally, for being such a big part of my journey and supporting me through my time in this PhD position. I would particularly like to thank Frank, Aniek, and (DRIFT alumnae) Antonia and Katharina for their insights and advice on how to finish a PhD, from their experience before me. To Maryce for making life easier by handling administrative matters and for offering support (and catching up with each other about our latest workouts every morning when picking up my laptop). To Sophie and Martin for their time and support in proofreading my Dutch translation of the summary of my dissertation. To my birthday buddy Igno for greeting me with a hug every time I walked into the office. To Julia for being a beam of light and an intellectual inspiration to me during my PhD. Finally, to PJ for having the most contagious laugh of anyone I know, that never failed to bring a smile to my face when I heard it in the distance, no matter my level of concentration at work.

To my parents, Dwight and Debbie, for being my unwavering support since day one. I am eternally grateful for their kindness, understanding, and encouragement to continue forward (including when I momentarily considered quitting everything and starting a new life as a convenience store clerk in rural Missouri). Their raising of me equipped me with the values and tools that formed the foundation for achieving every accomplishment in my life, without which I would never be publishing and defending a PhD now. I am so very grateful to them for our many calls, the few crises they talked me

down from, and their sporadic visits to see me in the Netherlands (which also brought suspiciously good weather every time). With their combination of both emotional and book intelligence, I have always had the two best advisors supporting me in my life.

To my brother Theo, wise beyond his years, who also offered me important counsel during my journey. I especially thank him for sending me periodic goofy pictures and texts that randomly brought laugh-out-loud comic relief on tough or dreary days.

To my companions in navigating all the craziness that is a PhD journey: I thank Elena, Dea, and Dilnoza for our calls and check-ins with each other throughout our similar PhD timelines. It has been amazing to share experiences and grow up together in our careers, allowing us to continuously strengthen our unique relationships as both close friends and academic peers.

To all my friends at Sportja, who were my social support and liveliness at the gym, and who also allowed me space when I had written so much during the day that I had no more sentences left in me to speak. These people especially include: Felix, Sybren, Miranda, Wouter, Joost, Sandra, Zoë, Arwin, Lizanne, Bram, and all the trainers who made the outdoor "Winter Wonderland" and summer "Muscle Beach" lifting spaces possible during the COVID-19 lockdowns. This gym and crew gave me positive energy, social contact, and renewed motivation every day when those assets were particularly hard for everyone to come by during the strict pandemic measures.

To Caroline, who was my sounding board over the past year and who taught me – when considering everyone else's needs and schedules – to also start considering and prioritizing my own.

To Marilou for her enthusiastic work on the great layout and collaborative cover design of my thesis – it was a pleasure working closely together in these final steps for publication.

To my friends (on top of those already mentioned) who helped me keep things light, including Kathelijne, Marijke, Loïs, Linda, Michelle, Angelina, Lara, Vigil, Frank, Kevin, Mark, Jay-el, Julius, Dave, Thanos, Lauren, and Christina. I am thankful for our rollerblading adventures through the dunes, forests, and tulips; for our bike rides together to the beach every sunny day of summer vacation; for the many borrels and "wijntjes" on a terrace in the sun; and for all the festivals and for our dreamlike travel adventures together – these memory-making times brought the "life" into my work-life balance.

Lastly, I would like to thank my MIND (MSc Industrial Ecology) colleagues, coordinators, and the Erasmus Mundus master's program overall, which allowed this enthusiastic American to move across the world to live out her dream of living and studying in Europe as a young 20-something. Without this first big move (and the knowledge foundations from this incredible master's program), it is unlikely I would have ever found this PhD position in the Netherlands, the place I now love and call my home.

TABLE OF CONTENTS

1

INTRODUCTION

It is long known that there is increasing strain on the world's finite set of resources (Burger & Gochfeld, 1998; Dietz & O'Neill, 2013; Hall & Day, 2009; Naylor et al., 2009; Schulte, 2013) and that society is consuming them at an unprecedented, unsustainable rate (Gao & Tian, 2016; Ramakrishnan, 2001; Wang et al., 2021). Even extending back half a century, scientists and scholars were observing the powerful and frequently negative effect humans have on the natural world as a result of production and consumption patterns, already warning about the negative impact this could have on current and future generations, for example: Rachel Carson's *Silent Spring* (1962), the Club of Rome's *Limits to Growth* (1972), Schumacher's *Small is Beautiful* (1973), and the UN's Brundtland report (1987). The very first UN conference on environmental issues, the 1972 UN Conference on the Human Environment held in Stockholm, Sweden, adopted fundamental principles in this regard. The Stockholm Declaration addressed resource depletion and the objective to ensure that natural resource use benefits not only the few, but the many, both within and across countries. It spoke to the principle of intergenerational equity: ensuring that today's resource use does not compromise the availability of natural resources for future generations – as relating to social justice, environmental health, and economic development. The sustainable use of natural resources strives for a balance between these dimensions – maintaining the long-term use of resources while maximizing social benefits and minimizing environmental impacts (Bansard & Schroder, 2021).

Since this time, there has been a growing awareness about the necessity for western societies to consume less in a not-so-distant future. Thus, it has been increasingly suggested that earth's carrying capacity – the amount of humans (and respective consumption) that the earth can hold before quality of life significantly declines (Rees, 2018) – will be exceeded if current consumption patterns in the industrialized world continue or are replicated by developing nations. Resource management began to receive significant and increasing cultural and political strength and importance, with studies at that time already suggesting that continued rates of growth in resource consumption would produce imminent shortages (Kincaid, 1983). Now, we are seeing this unsustainable use of resources replicated in areas of the Global South – as predicted, with progressive industrialization, resource use increased; in some cases, exploitation levels came to exceed resources' natural regeneration rates, such as those described in Earth overshoot day (Ramakrishna, 2021) and planetary boundary reports (Rockström et al., 2009; Steffen et al., 2015). Such collective overexploitation ultimately threatens the environment, and thereby, the livelihood and wellbeing of the people in society who depend on these resources.

There is hardly any consumption activity completely devoid of environmental impacts, making the ever-increasing level of consumption an important contributor to resource depletion and environmental degradation in its own right (European Environment Agency, 2010). The United Nations Sustainable Development Goal 12, aimed at responsible consumption and production, outlines metrics to achieve by 2030 that current material needs do not lead to the over-extraction of resources or to the degradation of environmental resources – especially in the context of rapid consumption, heavy dependence on non-renewable resources, and a 13% rise in population expected by the end of the next decade (United Nations, 2019). Thus, there is an increasingly urgent need to make a significant change in our current production and consumption patterns.

Yet, despite knowledge about overconsumption and forms of addressing the increasingly pressing issue existing, the global average material demand has only grown since the beginning of attention to it: from 7.4 tons per capita in 1970 to 12.2 tons in 2017, with significant adverse impacts on the environment (UNEP & IRP, 2020). Emerging from this growing societal awareness of the urgency to assess and reduce material consumption and extraction are terms such as ecological footprint (Wackernagel & Rees, 1996), material footprint (Wiedmann et al., 2015), and earth share (Peattie & Collins, 2009) as ways to address and measure these unsustainabilities in production and consumption patterns. Still, global extraction rates have more than tripled since the baseline year of 1970: from 27 billion tonnes to 92 billion tonnes (UNEP & IRP, 2020). In the year 2020 (± 6), the anthropogenic human-made mass on earth, which has recently doubled roughly every 20 years, surpassed all global living biomass (Elhacham, 2020). In light of these mounting material, resource, and environmental threats, the IPBES Global Assessment Report (2019) underscores a key message of my dissertation: transformative change is necessary to protect the earth's natural resources upon which human life and wellbeing depends.

In response to these threats of unsustainability and the need for transformative change, alternative discourse is emerging in policy and research – including such topics as zero-waste, industrial ecology (IE), and life cycle thinking. In parallel, there are increasing initiatives around improving waste and resource management are appearing in practice, policy, business, and society. Yet, these sustainability goals cannot be reached in a gradual way through incremental innovations and implementations – what is needed is a more fundamental, structural, and systemic change. In policy and research, the current alternative strategy that has evolved over years has been framed as a *circular economy,* with increasing pressure surrounding this topic.

1.1. CONCEPTUAL FRAMING: CIRCULAR ECONOMY

It is becoming increasingly argued that we must rethink our economic, social, political, and technological systems that currently enable damaging production practices and wasteful resource consumption (Bansard & Schroder, 2021; Kjellberg, 2008). In our current business, practice, and general manner of dealing with resources, there is a reigning linear economy. The linear economy is an economic system that prioritizes economic growth above all and operates on a "take-make-waste" consumption paradigm. As described in the previous section, the call to find new ways of addressing grand societal challenges such as overconsumption and ever-increasing resource extraction has become more prominent in politics and academia (Schot & Steinmueller, 2016). The concept of a circular economy (CE) has become a popular concept in literature, research, policy, practice, and business to address this. As stated by Bansard and Schroder (2021), we need "fundamental shifts in production and consumptions patterns, careful attention to value and supply chains, and the fostering of circular resource use and circular economies. Resource circularity breaks with the linear model of 'extract-use-discard' towards a 'waste-as-a-resource' model that fosters a reduced need for resource extraction, as well as encourages increased reuse, repair and recycling. These objectives are already enshrined in the 2030 Agenda for Sustainable Development, with governments aiming to achieve sustainable management and efficient use of natural resources by 2030" (p. 8-9). These goals and principles set the foundation for my PhD topic on circular economy.

The core principles of circular economy are based on the R-imperatives (Potting et al., 2017; Sihvonen & Ritola, 2015; van Buren et al., 2016), the waste hierarchy (Toxopeus et al., 2015), and systems thinking (Zhijun & Nailing, 2007). According to an analysis of 114 circular economy definitions by Kirscherr et al. (2017), CE is "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers" (p. 228). Similarly, the Ellen MacArthur Foundation – one of the leading world institutes on accelerating the transition to a circular economy – describes a three-prong definition of principles of the circular economy, driven by design (Ellen MacArthur Foundation, 2021):

1. Eliminate waste and pollution: Consider waste and pollution as design flaws rather than inevitable by-products of the things we make, to ensure they are not created in the first place.
2. Circulate products and materials: Design products to be reused, repaired, or remanufactured, increasing landfill diversion.
3. Regenerate nature: Return nutrients to the soil and other systems to enhance natural resources.

Some work has been conducted with a multi-dimensional consideration of CE implications, (e.g., Aguilar-Hernandez et al., 2021; Iacovidou et al., 2017; Lozano et al., 2021), but the majority of research in this field analyzes only one element emphatically. Part of the nature of this thesis is to take an integrated approach to studying CE and to draw attention to all broader impact areas of sustainability: including the most focused-on environmental aspect, but also and equally the economic, social, and legal dimensions, which are often overlooked or excluded in circularity research.

While circular economy is a notion not without critiques (Corvellec et al., 2021; Gregson et al., 2015; Hobson, 2016), supporters' enthusiasm for the paradigm often comes without a critical understanding of what it entails. Circularity is often seen as the goal in and itself, e.g., when portrayed and interpreted by the Circularity Gap Report (2021) that states we are 8.6% circular or national Dutch legislation aiming for the country to be 100% circular by 2050 (Rijksoverheid, 2021). Yet, this metric and increasing its value is not the purpose – rather, the goal is increasing what the metric represents: i.e., environmental sustainability, economic prosperity, and social justice across the world. Chasing a number can sometimes lead to overlooking tradeoffs; in my thesis, I examine paradoxes and tensions that result as a consequence of actions intended to create desired change and explore ways forward to deal with such dilemmas and tensions.

1.2. THEORETICAL FRAMING: TRANSITIONS AND GOVERNANCE RESEARCH

One suitable approach for studying circular economy is through a transition lens. Transition research is the study of the fundamental societal shifts in cultures, structures, and practices that take place in a complex, non-linear fashion over decades or generations (Grin et al., 2010; Loorbach & Rotmans, 2010; Markard et al., 2012). It is an interdisciplinary field bringing together elements of studies on complexity, policymaking, governance, and innovation (Geels & Schot, 2007; Smith & Raven, 2012) – applying a systems-thinking approach to study socio-technical influences, interactions, innovations, and impact. It can also be considered a type of post-normal

science, representing a novel approach for "the use of science on issues where facts [are] uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz & Ravetz, 1993, p. 1). The field of transition research emerged from the realization that "new research approaches are required to investigate the dynamics of complex societal problems and to guide the development of system solutions to address them" (Loorbach et al., 2017, p. 603). Transition research applies this perspective to complex societal systems, asking how these could make a structural qualitative shift from persistent unsustainability toward a more sustainable state (ibid). The field is rooted in multiple disciplines, including innovation studies, evolutionary economics, institutional theory, and complexity theory.

A transition is conceptualized as a fundamental change in the dominant cultures, structures, and practices in a societal (sub)system, as a result of a co-evolution of economic, technological, institutional, cultural, and ecological developments at different scale levels. Transitions are long term (25–50 years), highly complex and contested, and often cut across a variety of domains and stakeholders (Grin et al., 2010). Contemporary transitions are often related to sustainability goals in order to resolve a number of persistent problems confronting modern societies. We usually speak about transitions with the normative framing of "desired" transitions, particularly in the context of sustainability transitions. In sustainability transition analyses, possible pathways are made explicit: how can we get from Point A – the status quo – to Point B – the desired future scenario. For all intents and purposes, for the rest of this thesis, the single word "transition" can be understood to mean "sustainability transition."

1.2.1. Transition management and developments in the field

Transition management (TM) is a main lens I used to explore the primary field of my thesis, circular economy. TM developed as a new mode of governance focused on facilitating radical long-term change through empowerment of transformative agency, by building up capacities and developing new network coalitions with shared transition agendas (Loorbach, 2010; Loorbach et al., 2020). It "emerged from transition theory, which outlines that persistent problems need fundamental changes in structures, cultures, and practices of ongoing societal systems. Its perspective on the world is highly complex, uncertain and dynamic, thus allowing a multitude of pathways to sustainability. Transition management targets fundamental change, while both stimulating societal critique and challenging the status quo" (Wittmayer et al., 2014, p. 11). Despite some advances in recent years in circular economy, it has not become the norm and is still in the beginning stages of its transition. For this reason, I have applied transition science (and relatedly, TM) as a lens, with the aim of unlocking new insights in the CE field.

TM provides a theoretical approach and tools for navigating transitions, but it has been under-operationalized for the CE transition. By this, I mean that there is prevalent talk about, support for, and enthusiasm surrounding the transition to a circular economy – particularly in the Netherlands, where my research was based. There is lots of buzz around the term, but there is still no commonly understood and agreed upon operationalization of what exactly it is, the point at which we will have "achieved" it, what the specific and concrete steps are to move forward, and which innovations to support to get there. There is increasing financial support being made available for the development of circular innovations, but I argue that this needs to be channeled to approach a particular process and end goal. Accordingly, through my PhD, I attempt to offer contributions and guidance in navigating these currently still fuzzy pathways. In this thesis, I identify specific characteristics and challenges relating to the physical reality of CE transition: resources and how they are embedded in economic processes. Taking a physical-material and conceptual-theoretical starting point, I identify crucial *paradoxes* that are so far not identified and that have important implications for governance approaches to this transition. By "paradox", in my thesis I refer to a contradictory statement or proposition which when investigated may prove to be well-founded or true. Transition management addresses the "how" of guiding a desired transition, but it does not always make apparent for actors or decision-makers how to autonomously identify and navigate the dilemmas that may arise underway. Because of this, and as a result of my CE research, I was also able to identify some gaps and uncertainties in the transitions field, from which I found new insights through the development of my thesis research (see e.g., Chapter 3 and 7).

1.2.2. Transition dynamics

The analysis of a transition starts with an understanding of changes at three different levels of aggregation that play a role in these societal transitions (Geels, 2004; Geels & Schot, 2007; Smith et al., 2010), as shown in Figure 1. The *regime* – as described by a fundamental framework in transitions literature, the multi-level perspective (MLP) – is the makeup of society's current dominant cultures, structures, and practices and is the dominant way in which a sector or area has historically evolved and become structured, traditionally characterized by vested interests and established routines (Geels & Schot, 2007). Despite the complex, global resource challenges identified decades ago, ambitious policy commitments, large scale investments in innovation, and voluntary actions – our economies continue to develop along unsustainable pathways and push ecological boundaries. This inability to change direction especially through controlled, managed, or incremental strategies has been the focus of the socio-institutional perspective in sustainability transitions research (Grin et al., 2010; Loorbach et al., 2017; Markard et al., 2012). One of the central problems addressed is that policy and

innovation are primarily geared towards optimizing existing regimes, leading to path dependencies and lock-in (Frantzeskaki & Loorbach, 2010; Kemp & Loorbach, 2003).

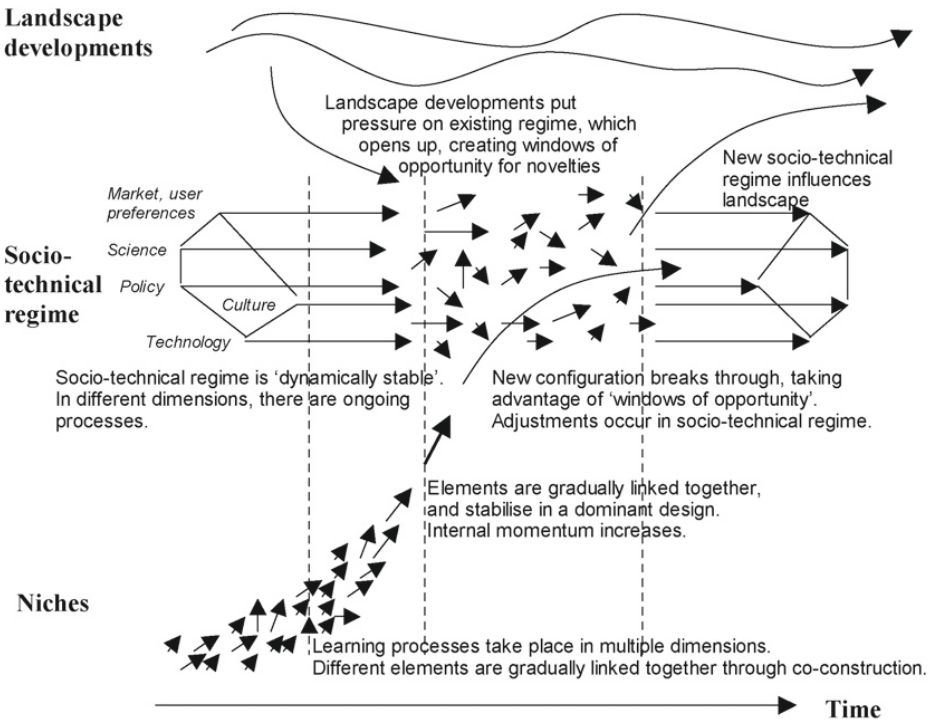


Figure 1: The Multi-Level Perspective, taken from Geels (2002)

From the Multi-Level Perspective (Geels, 2002), we can identify three dynamics happening in relation to the regime:

1. There are outside pressures on the regime – in this case, including decreasing stocks of natural resources and a decreasing capacity to sustain our current economic system. These contextual, i.e., *landscape*, factors create outside pressures on the regime and influence the current dominating cultures, structures, and practices.
2. Because of these landscape pressures, the regime starts to experience crises: for example, resource scarcities.
3. In response to these regime crises, *niches* begin to emerge. These include alternative business models and ways of thinking and operating (ibid); in the transition to a circular economy, one example of a niche in the food and beverage sector might include growing oyster mushrooms from coffee grounds.

From a transition perspective, dominant forms of policy and management are currently mostly prioritizing *optimization* – incremental improvement to the current regime – which thereby adds to the lock-in of societal systems (Loorbach et al., 2017). These incremental improvements often intentionally or unintentionally embed the assumption of continuing the current regime (and therefore, may lead to fostering existing aspects of the current regime), leading to reinforcing current *path dependencies*. Path dependence refers to when the decisions presented to and made by people are dependent on previous decisions or experiences made in the past, because of resistance to change. Path dependencies are "inevitable, because of sunk investments, benefits of scale, and the co-evolutionary dynamic within a regime. But such path dependencies over time ultimately imply the inability to change beyond optimization, hence causing systemic tensions and problems" (ibid, p. 605). These foundational concepts have been built upon to address actor roles, power, and governance (Hendriks, 2009; Meadowcroft, 2009; Shove & Walker, 2007, 2008; Smith & Stirling, 2010). For example, Avelino and Wittmayer (2016) have proposed a framework of different categories of actors at different levels of aggregation, pointing out that "a systematic understanding of actors and the (shifting) power relations between them is relevant both for the theoretical understanding of transition politics, as well as for the application of transition governance" (p. 629). These are relevant topics that will come up in my thesis chapters and offer the basis for some of my discussion.

1.2.3. The X-curve framework and dynamics

The diffusion of innovation, central to and generally adapted to mean diffusion of alternative practices and structures in transitions, is typically understood in terms of upscaling through learning effects and cost-reductions visualized through an S-shaped curve (Rogers, 2003). The *X-curve,* a tool created by Loorbach (2017) built on and nuancing previous transition management research and frameworks, adds a dimension to this by expanding the S-curve to account for breakdown dynamics of the current regime. The X-curve framework is a visualization of transition dynamics that visually emphasizes the co-evolutionary nature of the build-up, breakdown, and stabilization dynamics in transitions (Loorbach, 2014). Used in transitions mapping, the X-curve is a model that illustrates how external pressures can work together to cause a regime shift and can help actors, organizations, and researchers identify which policies, progress, and innovations belong to which sub-phases of a transition, shown in Figure 2. In this thesis, I will commonly refer to optimization, destabilization, experimentation, and acceleration, so I will define my understanding of these in the next paragraphs.

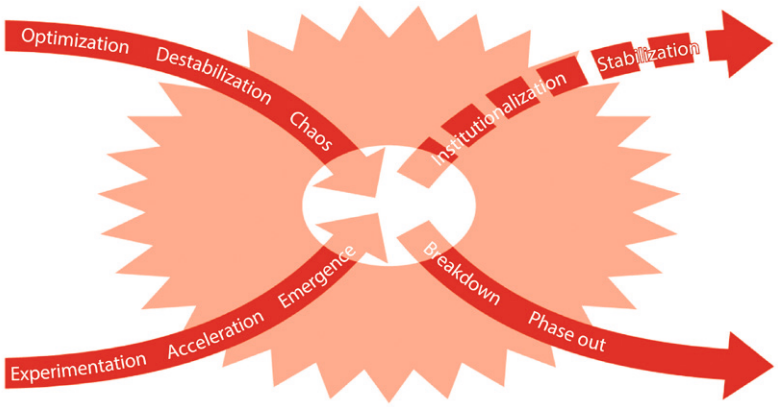


Figure 2. The X-curve, taken from Loorbach (2017)

To offer an elaboration on the dynamics shown in Figure 2: *experimentation* is the transition dynamic in which niche activity first begins, which may emerge as an alternative to the current regime. It is a space to learn and improve innovation activities with limited risks and resources through continuous and collective learning with stakeholders (Bocken et al., 2018). These niche experimentations may lead to:

1. *Optimization* of the current regime: incremental change in the current incumbent practices that slightly lessens the negative environmental impact the practice but serves as a reinforcing of path dependencies increasing inertia for the current unsustainable regime (Loorbach et al., 2017) – if they are not fundamentally different from the incumbent paradigm, or
2. They may lead to *destabilization* of the regime – a sudden loss of security, collapse of stable institutions and established organisations (Leipprand & Flachsland, 2018) –, if they are based on novel logics and gain critical mass to accelerate.

The latter case of destabilization may potentially lead to the *chaos* dynamic: ambiguity about the configuration of the future equilibrium-to-be (Rogge & Johnstone, 2017) – experienced in the uncertain space between two dominant regimes. In an absence of the stabilizing and coordinating effects of a regime, transition space forms, characterized by instability and volatility while also providing opportunities for transformative system change (Bosman et al., *forthcoming*). In transition space, practices from the old and the new regime co-exist and interconnect in unprecedented ways, new actor coalitions are formed in the process, and ongoing changes in rules and regulations as well as physical (infra)structures keep changing the systemic parameters within which actors operate – I refer to this in Chapter 4 as the *transition zone*. At the same time, processes of diffusion

and the self-organisational capacity of actors allow for new structures, routines, and organizational forms to emerge as *niche-regimes*. As originally described by de Haan and Rotmans (2011), "constellations providing a viable or even competitive functioning when compared to the regime and thus do have considerable power, although not dominating the functioning of the societal system are called niche-regimes" (p. 93). I will link these concepts in the discussion of Chapter 7 and add a novel conceptualization that I found relevant in the course of my research.

In my thesis, I call out optimizations of the linear economy regime, identify the multi-faceted role of incumbent actors and organization may have in the destabilization of the current regime, and explore dilemmas that may result from the tensions and paradoxes found in the chaos stage of a transition. I describe examples of experimentation in practice and offer insights about the acceleration dynamic of the transition to a circular economy. To understand how these dynamics are influenced, it is relevant to understand the idea of governance.

1.2.4. Governance and transformation

The general concept of governance is central to sustainability transitions, defined to be the totality of all the interactions of public and private actors aimed at solving shared problems or creating shared opportunities (Kooimans, 2003). Transition governance "can in turn be positioned in relation to the broader context of an environmental governance for transformation (Biermann & Pattberg, 2008; Galaz et al., 2012; Lemos & Agrawal, 2006) and sustainability governance (Elkington, 2006; Nooteboom, 2006)" (Loorbach et al., 2017, p. 613). This may include structures from centralized government to more civil self-organization of e.g., grassroots initiatives. Applying this concept to the idea of transition governance refers to the possibility of steering or influencing transitions towards the desired outcomes (Bosman & Rotmans, 2016; Loorbach, 2007; Loorbach, 2010). For governance, insights into the transition to a circular economy imply taking a much more fundamental and transformative approach: true circular decision-making is of peak importance.

It is commonly argued that incremental innovation and system optimization do not suffice in a transition, and socio-technical innovations that affect markets, practices, cultures, and policies are necessary; sustainability transitions research has shown that persistent sustainability challenges require system innovation, i.e., deep structural changes of the socio-technical configurations underlying the respective sectors (Markard et al., 2012; van den Bergh et al., 2011). The general assumption is that "transformative change requires current entrenched socio-technical configurations to be de-institutionalized and new ones to be created and diffused" (von Wirth et

al., 2019, p. 230). This creates a context in which other actors will look for alternative steps forward. Because of the persistent failure to reduce negative environmental impacts decisively, to facilitate long-term resilience against climate change, and to account for the connectedness of climate change with other social, environmental, and economic concerns, there has been a call for more transformative governance (Diercks et al., 2019; Hölscher et al., 2019). Looking at niches within this context, we encounter policy entrepreneurs and sustainable startups, among others. From a transformative governance view, the challenge is how to empower radical, desirable alternatives and nurture a space for transformation within a regime setting. In line with key literature, I will use the term "transformation" in this thesis to refer to non-linear systemic change that leads to fundamental, qualitative changes in societies' cultures, structures, and practices (Loorbach et al., 2017).

A regime is transformed if one or more of its core or constitutive rules change (van de Poel, 2003). I introduce the idea of *transformative governance* here to distinguish between governance that supports and undergoes incremental innovation, versus a type of governance that is vision-oriented, open to, and supporting transformative change: i.e., "large-scale changes in whole societies, which can be global, national or local, and involve interacting human and biophysical system components" (Hölscher et al., 2018, p. 2). The terms "transition" and "transformation" are not mutually exclusive (ibid), but an institution or society can be in the beginnings of a transition without any signs of transformation. Thus, this thesis also analyzes to what extent efforts, policies, entrepreneurships, and initiatives that belong to the transition to a circular economy are actually transformative. Yet, "the development of radical alternatives may be enabled by the innovation pattern of an existing regime. This is an important mechanism in addition to the process of development of alternatives in niches and the introduction of radical innovations by outsiders" (van de Poel, 2003, p. 66). Thus, in my thesis, I introduce and explore the complementary concept to the niche-regime within transition space: the *regime-niche*. This concept will be exemplified through a case in Chapter 3 and elaborated on further in Chapter 7.

Zooming out, in this PhD I investigate if circular initiatives are beginning to sum to a transition and what kind of direction and tools are needed to potentially accelerate progress more effectively in the transition. I explore these dynamics of change in society by taking an analytical transition perspective to examine what is currently happening in society and what the resulting implications for governance are.

1.3. METHODOLOGICAL FRAMING & KNOWLEDGE GAPS

As described in the previous two subsections, my research built upon circular economy and transition literature. The methodology for my thesis was a multiple methods approach combining literature reviews, interviews, empirical observations, international workshops, and conceptual innovation work. These methods were developed in order to seek to address the knowledge gaps found in the literature during my review and observed in practice during my empirical work. These are outlined in the rest of this subsection, along with my approach on how I intend to fill these gaps (described in further detail in Chapter 2).

In the literature and practice, there is substantial attention given to niche innovation. CE has innovation and experimentation, but there are hardly signs of a progressing transition. Many circular projects and initiatives at the experimentation level exist (Antikainen & Valkokari, 2016; Cainelli et al., 2020; Drabe & Herstatt, 2016; Horbach & Rammer, 2020). Likewise, the stories of transition dynamics in research have been studied heavily from the perspective of the niche (e.g., Feola & Nunes, 2014; Moore & Westley, 2011; Seyfang & Smith, 2007). It is clear that there is significant attention given to innovation, but perhaps there is not enough attention on the slower-moving, larger gears in the mechanics of systemic change and how to facilitate change from this perspective. The trend of research on the upscaling and emergence of niches in transitions literature makes studying the complementary half to this body of research interesting to study as an avenue for furthering and progressing in desired transitions.

Transition governance research posits that actors embedded in a societal regime are too constrained by entrenched institutions and path dependencies to shift structurally or respond to opportunities arising from experimental initiatives (Loorbach et al., 2017). Yet, other important transition scholars have noted that "empirical applications tend to depict regimes as too 'monolithic' and 'homogenous', not adequately considering persistent institutional tensions and contradictions" (Fuenfschilling & Truffer, 2014, p. 772). Innovation within a regime context has been until now mostly overlooked, but transition research is evolving, and with it, our understanding of the conceptualization of experimental initiatives. For example, a recent work by Grin et al. (2020, p. 682) touches on this: "Urban experiments are no longer exclusively undertaken by alternative networks, dominated by new actors and alliances and located at the fringes of the current system. A second generation of initiatives is emerging, which is characterized by a leading role for local governments, together with other established players". Still another piece of research describes the proactive incumbent (Hengelaar, 2017), but a nuanced approach of intra-regime dynamics as a potential vehicle for transformative

change is scarcely found. To address this gap, in my dissertation I nuance between elements within a regime context, and I describe potential pathways to transition to a circular economy in which elements of the regime might act as vehicles for transformative change.

A persistent problem in society is that circular initiatives and policies exist and are forming, but they are not yet translating into a transition. To date, there is no systemic understanding of if – or how to make – circular initiatives add up to transformative impact, rather than discrete circularity initiatives not meaningfully contributing to the shift to a new paradigm, or worse: counteracting it through optimizations (gone wrong) and reinforcing the incumbent linear economy. One possible reason for this is a lack of circular decision support tools in practice. Some circular economy-adjacent decision-support tools (DST) exist, such as for resource recovery from urban wastewater (Sucu et al., 2021) and natural resource management (Zapata & Ashby, 2003), but researchers including Tatichi et al. (2015) have identified the lack of integrated performance frameworks and called for a new generation of decision-support tools. I address this gap in my thesis by fusing Industrial Ecology and resource management frameworks with principles of innovation diffusion and integrating reflexive monitoring – bringing these three elements together in a novel, interdisciplinary way in a format also incorporating environmental decision-making. Still, the question remains concerning what happens in the space between two regimes when one transitions to another, and what role regime actors and elements might play in supporting desired transition. For this reason, in my thesis, I explore the dynamics and elements of a CE transition, identify key tensions and paradoxes in the transition, and offer ways to address these dilemmas. I dive into the question of if the current circular policies and initiatives are truly transformative in nature, or if they are just adding up to more of the same linear outcomes. Further, I explore what governance may be necessary to empower and facilitate such a transformation, i.e., a true transition to a circular economy.

1.4. RESEARCH QUESTIONS AND STRUCTURE

In seeking to address the knowledge gaps discussed in the previous subsections, the main research questions of this thesis are as follows:

What are the key dynamics in the transition to a circular economy, and what does that imply for strategy and governance?

- How do niche innovations interact with incumbent actors and institutions?
- What key tensions, paradoxes, and dilemmas do actors face in the transition to a circular economy?
- What kind of new decision-making logic is needed to address these tensions and dilemmas?
- How could such a new circular decision-making logic be applied to navigate decisions in the transition to CE in a particular sector?

These research questions are addressed by the empirical and conceptual insights brought forward in the following four chapters (Chapter 3-6), each of which unveils a misunderstanding surrounding circular economy and responds to each research question respectively. The major content sections of the thesis begin by describing 15 principles for connecting niche innovation with incumbent practice observed through empirical work, directly studying a case of upscaling (Chapter 3). Then, I identify a noteworthy paradox that emerges in the transition to a circular economy and discuss four key related practical dilemmas resulting in implications for CE (Chapter 4). In response, the following chapter offers a promising tool for navigating circular decisions, also as related to the aforementioned paradox, based on a different logics system (Chapter 5). Lastly, I apply this newly developed decision-making framework as a tool to explore the state of transition to CE, barriers thereof, and potential facilitators of CE a particular context and sector (Chapter 6).

The chapters consist of two articles published in a peer-reviewed high-impact journal, one article accepted for publication with revisions, and one chapter applying learnings from these papers (to be submitted for publication in due time); see Table 1 for details and citations. The dissertation as a whole is introduced in this current chapter (Chapter 1). The following chapter describes my research methodology and the layered contexts within which it is set (Chapter 2). Then, the aforementioned articles are presented in consecutive, logical order (Chapters 3-6). Lastly, the key insights and main contributions from my thesis package are synthesized into concluding discussions and remarks, and future research on topics encountered in my PhD (but not focused on) is proposed (Chapter 7).

Table 1: Scientific articles written and contained in the thesis

Chapter	Authors and title	Abstract
3	Greer, R., von Wirth, T., & Loorbach, D. (2020). **The diffusion of circular services: Transforming the Dutch catering sector.** *Journal of Cleaner Production*, 267, 121906.	Alternative ways to provide services based on circular economy principles are facing the problem of diffusing beyond local experimentations in niches to become mainstream. This is the entry point for our case study examining niche experimentation in the form of circular catering as developed within the urban living lab BlueCity010 in Rotterdam, the Netherlands, and how it interacted with incumbent actors. This case sets itself against the background of the national policy program "Circular Netherlands in 2050" and larger socio-political efforts to accelerate the transition to a circular economy in the Netherlands. Through a stakeholder analysis and in-person interviews, qualitative data was extracted that helped to map the process of diffusion, the inherent power dynamics, and connecting mechanisms between niche and current regime actors. The results detail various manners through which niche and regime actors connect, including actions taken to facilitate the diffusion of circular catering and settings that created a favorable environment. Our findings also include quantitative values for indicators of success from a Dutch ministry (e.g., CO_2 emissions range, percent of animal protein, reduction of food waste), which appear in their very preliminary stage to be on track for meeting their circularity goals within catering. Our research offers novel empirical insights into how to increase and scale cleaner production practices towards a circular economy through circular startups, summarized into 15 observed principles for connecting and integrating niche innovations to incumbent practices. Lastly, these observed practices are discussed in connection to sustainability transitions and in terms of their potential generalizability to cleaner procurement.
4	Greer, R., von Wirth, T., & Loorbach, D. (2021). **The Waste-Resource Paradox: Practical dilemmas and societal implications in the transition to a circular economy.** *Journal of Cleaner Production*, 303, 126831.	The European Union has vowed to transition from a linear to a circular economy (CE). Many innovations, new business models, and policies have begun to emerge to support the push for further institutionalizing CE practices. A large portion of these attempts are based on transforming a flow currently labeled as a waste stream into a value proposition, i.e., a resource. However, this ironically increases the risk of creating a demand for these waste streams, which thereby may become commodified. In this article, we unpack the inherent dilemmas and implications created by this phenomenon, which we define as the Waste-Resource Paradox (WRP). Understanding the WRP is highly relevant, as its manifestation may lead to situations in which the further establishment of "circular" practices may reinforce linear economy by sustaining a waste (over) production in the system or causing undesired social or environmental repercussions. This can tighten a lock-in of the existing linear structures counteractive to CE that have not been explicitly identified or explored to date. We observed that the WRP may evolve and morph throughout time, across boundaries or respective to different societal sectors. Based on our findings, we highlight the profound implications of the WRP for the future of circularity and the potential consequences for a transition to CE.
5	Greer, R., von Wirth, T., & Loorbach, D. (*in revision*). **The Circular Decision-Making Tree: An operational framework** [Manuscript accepted with revisions to *Circular Economy and Sustainability*].	Because of the need to limit extraction of raw materials and reduce amounts and impacts of waste, countries and businesses are challenged to transition to a circular economy: an economic system in which the materials are reduced, reused, or recycled, but not wasted. Yet, transitioning from a linear to a circular economy implies societal-level, structural changes that have deep implications for existing business models and practices – and the current economic system is still largely organized around virgin material extraction and linear modes of production and consumption.

Table 1: (Continued)

Chapter	Authors and title	Abstract
5		Leading reports from the European Union and the Netherlands Environmental Assessment Agency (PBL) indicate that the aspiration to become circular has not sufficiently translated into a transition. One important reason why the transition towards a circular economy is not proceeding as quickly is likely to be found in the decision processes used by companies, investors, and policy makers. Suitable decision-making processes and frameworks could thus be a key enabler of this transition, if based upon a circular, transformative, rather than a linear optimization logic. In this paper, we therefore explore a different decision-making logic that is developed based on circularity. This provides the basis for an operational framework designed to help decision-makers such as policymakers, investors, and entrepreneurs navigate trade-offs and take decisions considering the quality of innovation circularity and its respective diffusion potential. To develop, test, and refine our framework, the "Circular Decision-Making Tree", we synthesized insights from existing frameworks and conceptually integrated these with our understanding of the transition management and circular economy. We then tested the internal logics and applicability of the decision-making tree in a series of usability workshops across four application contexts (Netherlands, Brazil, United Kingdom, and South Africa) with feedback from a total of 50 stakeholders from policy, practice, and academia – the results of which we reflect on in the discussion. To conclude, we reflect upon the limitations of our work so far and suggest further application potentials of the circular decision-making logic and tool.
6	Greer, R., von Wirth, T., & Loorbach, D. (2022). **Towards circular economy in the French wine sector: Applying the Circular Decision-Making Tree** [Unpublished manuscript].	Given the earth's finite set of resources and unwavering resource consumption trends, many sectors in various contexts are experiencing increasing pressures on biodiversity and resource use from society changing, causing increasingly problematic developments. In response to this increasing societal unsustainability, the concept of a circular economy has emerged as one widely supported strategy for reducing material consumption and waste in policy, research, and practice. Not immune to these issues – and, in some ways, especially related for their impact on and acute vulnerability to climate change effects – is the practice of viticulture and winemaking. It is still overlooked how we as a society can best strategize within complex and persistent environmental sustainability issues in this sector, given that many material-reducing practices in the wine sector focus on end-of-life solutions. In this exploratory study, we present an illustrative application of a conceptual framework and heuristic for circular decision-making in the wine sector. Because of its dominance in the global wine market, yet scarce signs of transformative practices over linear economy optimizations, we selected France as our geographical scope. In this paper, we investigate the potential usefulness of the circular decision-making framework through an illustrative application in this paper. Through our analysis illustrating the application of the tool – the Circular Decision-Making Tree (CDMT) –, we reflect on possible sector-specific barriers to CE and potential facilitators for improved circular innovation implementation in the French wine sector in our analysis. We conclude with a summary and final thoughts on the limitations and implications of our findings, as well as recommendations for future research.

1.5. REFERENCES

Aguilar-Hernandez, G. A., Rodrigues, J. F. D., & Tukker, A. (2021). Macroeconomic, social and environmental impacts of a circular economy up to 2050: A meta-analysis of prospective studies. *Journal of Cleaner Production*, *278*, 123421.

Antikainen, M., & Valkokari, K. (2016). A framework for sustainable circular business model innovation. *Technology Innovation Management Review*, *6*(7).

Avelino, F., & Wittmayer, J. M. (2016). Shifting power relations in sustainability transitions: a multi-actor perspective. *Journal of Environmental Policy & Planning*, *18*(5), 628-649.

Bansard, J., & Schroder, M. (2021). International Institute for Sustainable Development. Accessed on 21 December 2021 from https://www.iisd.org/articles/sustainable-use-natural-resources-governance-challenge

Biermann, F., Pattberg, P. (2008). Global environmental governance: taking stock, moving forward. Annu. Rev. Environ. Resour. 33:277–94.

Bocken, N. M., Schuit, C. S., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental innovation and societal transitions*, *28*, 79-95.

Bosman, R., & Rotmans, J. (2016). Transition governance towards a bioeconomy: A comparison of Finland and The Netherlands. *Sustainability*, *8*(10), 1017.

Burger, J., & Gochfeld, M. (1998). The tragedy of the commons 30 years later. *Environment: Science and Policy for Sustainable Development*, *40*(10), 4-13.

Cainelli, G., D'Amato, A., & Mazzanti, M. (2020). Resource efficient eco-innovations for a circular economy: Evidence from EU firms. *Research Policy*, *49*(1), 103827.

Carson, R. (2002). *Silent spring*. Houghton Mifflin Harcourt.

Circularity Gap Report. (2021). Circle Economy. Accessed on 21 December 2021 from https://www.greengrowthknowledge.org/research/circularity-gap-report-2021

Corvellec, H., Stowell, A. F., & Johansson, N. (2021). Critiques of the circular economy. *Journal of Industrial Ecology*.

de Haan, J. H., & Rotmans, J. (2011). Patterns in transitions: understanding complex chains of change. *Technological forecasting and social change*, *78*(1), 90-102.

Diercks, G., Larsen, H., & Steward, F. (2019). Transformative innovation policy: Addressing variety in an emerging policy paradigm. *Research Policy*, *48*(4), 880-894.

Dietz, R., & O'Neill, D. (2013). *Enough is enough: Building a sustainable economy in a world of finite resources*. Routledge.

Drabe, V., & Herstatt, C. (2016, July). Why and how companies implement circular economy concepts–The case of cradle to cradle innovations. In *R&D Management Conference from Science to Society–Innovation and Value Creation* (pp. 3-6).

Elhacham, E., Ben-Uri, L., Grozovski, J., Bar-On, Y. M., & Milo, R. (2020). Global human-made mass exceeds all living biomass. *Nature*, *588*(7838), 442-444.

Elkington, J. (2006). Governance for sustainability. *Corporate governance: an international review*, *14*(6), 522-529.

Ellen MacArthur Foundation. (2021). Accessed on 21 December 2021 from https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

European Environment Agency (2010). The European environment – state and outlook 2010: Synthesis Chapter 4: natural resources and waste. Accessed on 21 December 2021 from https://www.eea.europa.eu/soer/2010/synthesis/synthesis/chapter4.xhtml

Feola, G., & Nunes, R. (2014). Success and failure of grassroots innovations for addressing climate change: The case of the Transition Movement. *Global Environmental Change*, *24*, 232-250.

Frantzeskaki, N., & Loorbach, D. (2010). Towards governing infrasystem transitions: reinforcing lock-in or facilitating change?. *Technological Forecasting and Social Change*, *77*(8), 1292-1301.

Fuenfschilling, L., & Truffer, B. (2014). The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Research policy*, *43*(4), 772-791.

Funtowicz, S. & Ravetz, J. (1993). "Science for the post-normal age", *Futures*, 31(7): 735-755.

Galaz, V., Biermann, F., Crona, B., Loorbach, D., Folke, C., Olsson, P., ... & Reischl, G. (2012). 'Planetary boundaries'—exploring the challenges for global environmental governance. *Current Opinion in Environmental Sustainability*, *4*(1), 80-87.

Gao, J., & Tian, M. (2016). Analysis of over-consumption of natural resources and the ecological trade deficit in China based on ecological footprints. *Ecological Indicators*, *61*, 899-904.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), 1257-1274.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research policy*, *33*(6-7), 897-920.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy*, *36*(3), 399-417.

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.

Grin, J. (2020). 'Doing'system innovations from within the heart of the regime. *Journal of Environmental Policy & Planning*, *22*(5), 682-694.

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

Hall, C. A., & Day, J. W. (2009). Revisiting the Limits to Growth After Peak Oil: In the 1970s a rising world population and the finite resources available to support it were hot topics. Interest faded—but it's time to take another look. *American scientist*, *97*(3), 230-237.

Heiskanen, E., & Pantzar, M. (1997). Toward sustainable consumption: Two new perspectives. *Journal of Consumer policy*, *20*(4), 409-442.

Hendriks, C. M. (2009). Deliberative governance in the context of power. *Policy and Society*, *28*(3), 173-184.

Hengelaar, G. (2017). *The Proactive Incumbent: Holy grail or hidden gem?: Investigating whether the Dutch electricity sector can overcome the incumbent's curse and lead the sustainability transition* (No. EPS-2016-ERIM Series 438-ORG).

Hobson, K. (2016). Closing the loop or squaring the circle? Locating generative spaces for the circular economy. *Progress in Human Geography*, *40*(1), 88-104.

Hölscher, K., Frantzeskaki, N., & Loorbach, D. (2019). Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands. *Regional Environmental Change*, *19*(3), 791-805.

Hölscher, K., Wittmayer, J. M., & Loorbach, D. (2018). Transition versus transformation: What's the difference?. *Environmental innovation and societal transitions*, *27*, 1-3.

Horbach, J., & Rammer, C. (2020). Circular economy innovations, growth and employment at the firm level: Empirical evidence from Germany. *Journal of Industrial Ecology*, *24*(3), 615-625.

Iacovidou, E., Velis, C. A., Purnell, P., Zwirner, O., Brown, A., Hahladakis, 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.

IPBES (2019): Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673

Keeble, B. R. (1988). The Brundtland report:'Our common future'. *Medicine and war*, *4*(1), 17-25.

Kemp, R., & Loorbach, D. (2003). Governance for sustainability through transition management. In *Open Meeting of Human Dimensions of Global Environmental Change Research Community, Montreal, Canada* (Vol. 20).

Kincaid, H. L. (1983). Inbreeding in fish populations used for aquaculture. *Aquaculture*, *33*(1-4), 215-227.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.

Kjellberg, H. (2008). Market practices and over-consumption. *Consumption, Markets and Culture*, *11*(2), 151-167.

Kooiman, J. (2003). *Governing as governance*. Sage.

Leipprand, A., & Flachsland, C. (2018). Regime destabilization in energy transitions: The German debate on the future of coal. *Energy Research & Social Science*, *40*, 190-204.

Lemos, M. C., & Agrawal, A. (2006). Environmental governance. *Annu. Rev. Environ. Resour.* 31:297–325

Loorbach, D. (2007). Transition Management: New Mode of Governance for Sustainable Development. Ph.D. Thesis, Erasmus University Rotterdam, Rotterdam, Netherlands.

Loorbach, D. (2010). Transition management for sustainable development: A prescriptive, complexity-based governance framework. Governance, 23, 161–183.

Loorbach, D. (2017). Urban Sustainability Transition: Retrofitting the City. *Retrofitting Cities for Tomorrow's World*, 155.

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, 42, 237– 246.

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.

Loorbach, D., Wittmayer, J., Avelino, F., von Wirth, T., & Frantzeskaki, N. (2020). Transformative innovation and translocal diffusion. *Environmental Innovation and Societal Transitions*, *35*, 251-260.

Lozano, R., Bautista-Puig, N., & Barreiro-Gen, M. (2021). Elucidating a holistic and panoptic framework for analysing circular economy. *Business Strategy and the Environment*, *30*(4), 1644-1654.

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy,* 41(6), 955–967.

Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy sciences*, *42*(4), 323-340.

Meadows, D. H., Randers, J., & Meadows, D. L. (2013). *The Limits to Growth (1972)* (pp. 101-116). Yale University Press.

Moore, M. L., & Westley, F. (2011). Surmountable chasms: networks and social innovation for resilient systems. *Ecology and society*, *16*(1).

Naylor, R. L., Hardy, R. W., Bureau, D. P., Chiu, A., Elliott, M., Farrell, A. P., ... & Nichols, P. D. (2009). Feeding aquaculture in an era of finite resources. *Proceedings of the National Academy of Sciences*, *106*(36), 15103-15110.

Nooteboom, S. (2006). Adaptive networks. The governance for sustainability. *Erasmus University Rotterdam, Rotterdam, The Netherlands*.

Peattie, K., & Collins, A. (2009). Guest editorial: Perspectives on sustainable consumption. *International Journal of Consumer Studies*, *33*(2), 107-112.

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). *Circular economy: measuring innovation in the product chain* (No. 2544). PBL Publishers.

Ramakrishna, S. (2021). Circular economy and sustainability pathways to build a new-modern society. *Drying Technology*, *39*(6), 711-712.

Ramakrishnan, P. S. (2001). Increasing population and declining biological resources in the context of global change and globalization. *Journal of biosciences*, *26*(4), 465-479.

Rees, W. E. (2018). *Ecological footprints and appropriated carrying capacity: what urban economics leaves out* (pp. 285-297). Routledge.

Rijksoverheid. (2021). Nederland circulair in 2050. Accessed on 21 December 2021 from https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050

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

Rogers, E.M. (2003). Diffusion of innovations (5th ed.). New York: Free Press.

Rogge, K. S., & Johnstone, P. (2017). Exploring the role of phase-out policies for low-carbon energy transitions: The case of the German Energiewende. *Energy research & social science*, *33*, 128-137.

Schot, J., & Steinmueller, W. E. (2016). Framing innovation policy for transformative change: Innovation policy 3.0. *SPRU Science Policy Research Unit, University of Sussex: Brighton, UK*.

Schulte, U. G. (2013). New business models for a radical change in resource efficiency. *Environmental Innovation and Societal Transitions*, *9*, 43-47.

Schumacher, E. F. (2011). *Small is beautiful: A study of economics as if people mattered*. Random House.

Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental politics*, *16*(4), 584-603.

Shove, E., & Walker, G. (2007). CAUTION! Transitions ahead: politics, practice, and sustainable transition management. *Environment and planning A*, *39*(4), 763-770.

Sihvonen, S., & Ritola, T. (2015). Conceptualizing ReX for aggregating end-of-life strategies in product development. *Procedia Cirp*, *29*, 639-644.

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research policy*, *41*(6), 1025-1036.

Smith, A., & Stirling, A. (2010). The politics of social-ecological resilience and sustainable socio-technical transitions. *Ecology and society*, *15*(1).

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research policy*, *34*(10), 1491-1510.

Smith, A., Voß, J. P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research policy*, *39*(4), 435-448.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223).

Sucu, S., van Schaik, M. O., Esmeli, R., Ouelhadj, D., Holloway, T., Williams, J. B., ... & Cappon, H. J. (2021). A conceptual framework for a multi-criteria decision support tool to select technologies for resource recovery from urban wastewater. *Journal of environmental management*, *300*, 113608.

Taticchi, P., Garengo, P., Nudurupati, S. S., Tonelli, F., & Pasqualino, R. (2015). A review of decision-support tools and performance measurement and sustainable supply chain management. *International Journal of Production Research*, *53*(21), 6473-6494.

Toxopeus, M. E., De Koeijer, B. L. A., & Meij, A. G. G. H. (2015). Cradle to cradle: Effective vision vs. efficient practice?. *Procedia cirp*, *29*, 384-389.

UNEP and IRP. (2020). Sustainable Trade in Resources: Global Material Flows, Circularity and Trade. United Nations Environment Programme.

United Nations (UN). (2019). Accessed on 14 December 2021 from https://unstats.un.org/sdgs/report/2019/goal-12/

van Buren, N., Demmers, M., Van der Heijden, R., & Witlox, F. (2016). Towards a circular economy: The role of Dutch logistics industries and governments. *Sustainability*, *8*(7), 647.

van de Poel, I. (2003). The transformation of technological regimes. *Research policy*, *32*(1), 49-68.

van den Bergh, J. C., Truffer, B., & Kallis, G. (2011). Environmental innovation and societal transitions: Introduction and overview. *Environmental innovation and societal transitions*, *1*(1), 1-23.

von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229-257.

Wackernagel, M., & Rees, W. (1998). *Our ecological footprint: reducing human impact on the earth* (Vol. 9). New society publishers.

Wang, J., Cao, S. J., & Yu, C. W. (2021). Development trend and challenges of sustainable urban design in the digital age.

Wiedmann, T. O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., & Kanemoto, K. (2015). The material footprint of nations. *Proceedings of the national academy of sciences*, *112*(20), 6271-6276.

Wittmayer, J., Roorda, C., & van Steenbergen, F. (2014). Governing urban sustainability transitions–inspiring examples. *International Journal of Sustainable Development*, *15*(1), 19-36.

Zapata, V., & Ashby, J. (2003). Dissemination and application of decision support tools (DST) for natural resource management. *Research Towards Integrated Natural Resources Management*, *47*.

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

2

METHODOLOGICAL APPROACH AND UNDERPINNING WORLDVIEWS

In this thesis, I set out to research a developing movement that is not yet actualized: a transition to a circular economy. It is an idea and a concept, which policy and business are now striving towards in various contexts. In that regard, I was able to research how these ideas and concepts developed, how they are taken up by actors, and what the implications thereof are. At the same time, I had to take a more explorative approach when reflecting upon the impact of this development and its possible implications for the future. By taking a transition perspective, I hypothesized that the emergence of the idea of a transition to CE relates to an increasing destabilization of the linear economic model and might lead to a systemic transformation towards a radically different future state. In this section, I describe the methodological approach taken in my thesis and the scientific philosophy underpinning my work, to inform the reader of the influence these may have had on my research and how I interpreted the results. To structure this chapter, I will address the core interrelated components of the scientific process, organized by the natural chronological order of the research process, as described by Zolfagharian et al. (2019).

2.1. PHILOSOPHY OF SCIENCE

When we speak about the building blocks of research, our ontology describes "what is out there to know", while our epistemology answers the question of "what and how can we know about it" (Grix, 2002, p. 180). Axiology refers to the role of values and ethics in our research, stemming from our ontology and epistemology, and influencing our methodological approach (Geels, 2010). Our methodologies are the ways we can acquire that knowledge, with methods and sources constituting the procedures we can use to acquire it and the data we can collect (Grix, 2002). Together, these building blocks of research stem in an interrelated way from a philosophy of science. Thus, in this chapter, I address the components of the paradigmatic orientation of my research, as related to my ontological assumptions about the nature of transitions, epistemological assumptions about the nature and limitations of knowledge about transitions, and axiological assumptions related to the role of values and ethics within my research (Geels, 2010; Lincoln & Guba, 1985; Tashakkori & Teddlie, 2010; Zolfagharian et al., 2019). All of these have an impact on the methodology in my research, as well as the methods selected for the procedures taken for the studies, and the related data sources utilized. This in turn leads in part to the type of results acquired and my interpretation thereof. For this reason, in the following subsection, I introduce to the reader the scientific philosophy(/ies) underpinning my thesis research, particularly as related to transitions research.

2.2. ONTOLOGY AND EPISTEMOLOGY

As a scientist and researcher, I primarily subscribe to the scientific philosophy of pragmatism. With its origins attributed to philosophers such as John Dewey, William James, and Charles Sanders Peirce, "the essence of a pragmatist ontology is actions and change; humans acting in a world that is in a constant state of becoming" (Goldkuhl, 2012, p. 139). A pragmatist philosophy in transition research involves the ontological assumption that "the nature of transition research is complex, rich, and external to transition researcher. A transition is the practical consequence of ideas, and knowledge is valued for enabling actions to be carried out successfully. Transition involves a flux of processes, experiences, and practices" (Zolfagharian et al., 2019, p. 7). The epistemology of pragmatism relates to the idea that an aim of transition theories and knowledge is to enable successful action by focusing on relevant problems and informing future practice (ibid), motivating the direction of my thesis. In accordance with the principles described of this scientific philosophy, in my work, I was motivated not only to do research to increase analytical knowledge, but to create frameworks and understandings applicable in real-world settings – like the considerations related to the Waste-Resource Paradox (Chapter 4) and the decision-making framework of the Circular Decision-Making Tree (Chapter 5). I believe these simultaneously make a contribution to the collective academic and scientific knowledge, and I also addressed and developed the frameworks in these chapters with the intention that they could be utilized in real-world settings, inclusively for actors without extensive scientific training.

Following Dewey, pragmatism has also contributed to other fields and movements such as action research (Goldkuhl, 2012). Because there may be varying understandings of action research, I define action research here: "In general, action research can be understood as the collaborative production of scientifically and socially relevant knowledge, transformative action and new social relations through a participatory process" (Wittmayer & Schäpke, 2014, p. 484). Thus – while "action research" was not a methodology employed per se – similar to its goals, I intended to help people involved in study and to move to intended practical solutions. This includes, for example, the semi-structured interviews of Chapter 3 and focus group workshops of Chapter 5, which were designed to also have a layer of co-creation to the sessions. I will further discuss how the pragmatic and action-oriented approach to research can often be seen within my research methodology and methods, in the rest of this and the coming sections.

In addition to my principal scientific philosophy of pragmatism, elements of critical realism are also woven into my scientific philosophy and, thereby, into my thesis research. Critical realism is a philosophy that grew from Roy Bhaskar, who believed

that "the evidence we observe can come close to reality but is always a fallible, social, and subjective account of reality" (Sturgiss & Clark, 2020, p. 143). Features of critical realism "fit in well with the ontology of complexity that recognizes the synergistic nature of context and mechanisms where the addition of multiple elements results in more than the sum of the parts involved (Greenhalgh & Papoutsi, 2018)" (ibid, p. 143). This understanding may relate to the complexities of circular economy and transitions, through which I have studied a phenomenon with multiple, interconnected conditions that influence outcomes. I drew on a critical realist approach to help address research inquiries about how and why the transition to a CE might move from relating mostly to the "experimentation" to the "acceleration" or "emergence" construct of the X-curve described in Chapter 1 (Hebinck et al., 2022), within the complexities of transdisciplinary and interdisciplinary real-world contexts. I particularly touched on the critical realist idea about the synergistic nature of mechanisms when framing the case study of Chapter 3 and interpreting the results by compiling and categorizing the of the 15 principles in this paper analytically; together, they may have had an influence on the circular catering transition, something arguably more than the sum of its parts (i.e., the events and conditions that each may have had an individual influence).

Still, I subscribe only partially to the ontology of this philosophy. For example, I find transitions and their elements to be dynamic, given enough time, questioning the idea that "there are objective and intransient (relatively unchanging) structures and causal mechanisms in any transition process" (Zolfagharian et al., 2019, p. 7). Even though we as transition scientists assume this systemic and dynamic aspect of transition elements (transitions are dynamic subjects of study), we create a lot of categories that are analytical or static, such as the constructs of the X-curve – allowing for positioning of an element of a transition in terms of the state of acceleration of the new regime in interplay with the state of the breakdown of the old regime (Loorbach et al., 2017). We do assert that specific patterns and mechanisms are generic and thus intransient, because we assume there are "stable" patterns in dynamic structures, e.g., in acceleration or destabilization, which we may recognize empirically. Analytically, we have to work with more static categories and can observe patterns, although there is a lot of fluidity of states of transition in practice.

On the one hand, there is a more fluid, dynamic, intangible of our objects of study in transitions, while at the same time, we see some elements also showing this stability and continuity, and revealing certain patterns across contexts or societies. As transition scholars, we cannot shy away from nomenclature of unchanging structures or categorizations because transitions are so fluid and dynamic, but we try to analyze these more stable patterns that have led to lock-ins and dependences over time. In

Chapter 3, for example, I assumed there are some patterns that might show in other contexts that I have shown in these 15 principles for potentially priming acceleration. Because I have researched transitions-in-the-making, rather than a historical case study, this paradox between intransient structures and fluid components is inherently present, which I have navigated in my thesis. Mirroring Dewey's pragmatic assertion that "Because we live in a world in process, the future, although continuous with the past is not its bare repetition" (Dewey, 1929, p. 40) – I have taken a pragmatic approach in anticipating elements that might continue and in making an interpretation of how things will continue, but I acknowledge that everything remains highly uncertain, and I add an element of anticipation and interpretation. This is the rationale for including action research principles in my methodology, as described later in 2.1.3 – using this version of participatory methods in my research, with the aim to increase the collaborative production of relevant knowledge and transformative action to navigate this tension within the realm of circular economy, my principal subject of study.

2.3. AXIOLOGY

Axiology stems from ontology and epistemology. In research, "basic beliefs about what is ethical are embedded in research paradigms and guide the researcher's decision making" (Killam, 2013, p. 6). This means, axiology refers to values in research: including contextual transparency about the researcher's position and its implications for methodologies (Pontoretto, 2005). The axiology of my research, as directly related to my ontology and epistemology, also combines elements of pragmatism and critical realism. In the pragmatist sense, I believe that "transition research is value-driven and is initiated and sustained by the researcher's doubts and beliefs" (ibid, p. 7), since the elements of my work were created, researched, and developed in accordance with my interests and informed by my values within the field of circular economy. For example, this is the reason why I intentionally addressed the material, energy, economic, and social repercussions and tensions related to the WRP in the methodology and discussion of results in Chapter 4 – while much extant research on the subject primarily focuses on only one aspect of sustainability, e.g., environmental or economic.

The foundational pragmatist John Dewey suggested that "all human experience involves some amount of interpretation – interpreting knowledge and beliefs leads to action and reflecting on actions leads to new ways of knowing and acting" (Kelly & Codeiro, 2020, p. 2). Similarly, critical realists "accept a true reality but believe it can only be apprehended and measured imperfectly" (Ponterotto, 2005, p. 131). In transition studies, a critical realist's axiological thought is said to be that "transition studies are value-laden research. [The] transition researcher acknowledges bias by worldviews, cultural

experience, and upbringing. [The] transition researcher tries to minimize these biases and errors [and] is as objective as possible" (Zolfagharian et al., 2019, p. 7). For these reasons, in sections 2.3.1-2.3.4, I describe my project involvement, institutional context, and personal background. While we always strive to be transparent in our works as scientists and objective in our analyses, we are susceptible to being unintentionally and implicitly influenced in some small way by our background, experiences, and values; thus, it is valuable for the reader to understand the contextual and background factors present in my research. Following, the methodological implications of my axiology will be discussed in section 2.3.5.

2.3.1. Project context

This PhD was made possible through the project Waste FEW ULL, funded under the EU Joint Programming Initiative (JPI) Urban Europe and the Dutch National Science Foundation (NWO). The project ran for three years (June 2018 – June 2021), with a six-month extension (July 2021 – December 2021) that also carried over to my PhD, due to the worldwide COVID-19 pandemic onset in and continuation since the second year of the project. The project aim was to research ways to substantially reduce waste in the food-energy-water nexus in cities across three continents: Europe, Africa, and South America. This was to be done by developing and testing internationally applicable methods of identifying inefficiencies in a city-region's food-energy-water (FEW) nexus, through an international network of industry/civic society-led Urban Living Labs (ULL) in four urban regions: United Kingdom (Bristol), Netherlands (Rotterdam), South Africa (Western Cape), and Brazil (São Paulo). The project proposed to contribute policy tools for waste prevention and reduction. The emerging popularity of the FEW nexus reflects the ongoing transition from a sectoral approach to an integrative approach in addressing the global challenges pertinent to the three essential resources: food, energy, and water (Zhang et al., 2019). Although the FEW nexus did not end up being a major component of my thesis, it led me to my current orientation and interpretation of the assignment by researching circular economy, and it merits future research outside of this context.

2.3.2. Institutional context

Embarking on this project path led me to the Dutch Research Institute for Transitions (DRIFT) in Rotterdam, Netherlands. DRIFT is a leading research institute in the field of sustainability transitions that develops and shares transformative knowledge to support people, cities, sectors, and organizations to engage proactively with transitions. Through research in sustainability transitions and transition governance, we aim to accelerate transitions towards more just, sustainable, and resilient societies. The DRIFT team is an international and interdisciplinary group of researchers and advisors, with

backgrounds in environmental science, innovation studies, public administration, sociology, political studies, engineering, cultural analysis, and anthropology. It may also be of value to note that DRIFT takes the normative position that sustainability transitions are the "desired" transitions (Wittmayer, 2016; Loorbach et al., 2011; Wiek & Lang, 2016), which is echoed in my own work here. DRIFT is an open, mutually supportive group of researchers and advisors that combines academic rigor with reflexive activism. Because learning is a social activity and is directly associated with our connection with other people, our teachers, colleagues, peers, and acquaintances impact our learning (Amineh & Asl, 2015). Through my work and colleagues at DRIFT, I was encouraged to adopt a more "learning by doing" approach and was supported in growing as a scientist, a researcher, and a person.

2.3.3. Individual context

My cultural context during this project was framed by my American background and full embedding in the Dutch context, through assimilation of the language and culture in the Netherlands. My academic background includes a liberal arts university education in Psychology and a European Commission-funded international joint degree M.Sc. program in Industrial Ecology (IE), both inherently interdisciplinary studies, together including the study of social, human-centered sciences, as well as engineering, climate physics, and corporate social responsibility. As Zolfagharian et al. (2019, p. 2) posit, "Transition research is an interdisciplinary field, firmly rooted in the tradition of system thinking (Grin et al., 2010; Rodrigo et al., 2015). There is no agreed list of fields that constitute transition studies" – in my research, I have tried to integrate different disciplinary fields to create an interdisciplinary understanding of the phenomenon of the transition to a circular economy. At the forefront of these disciplines included in my research are the scientific fields of transition science, governance, sustainability, and industrial ecology.

Both the fields of IE and transitions are also similar in taking a systems-thinking approach, but there is a relative disconnect regarding the communication of results across disciplines. I observed this when attending the International Sustainability Transitions conference directly preceding the International Society for Industrial Ecology conference, hearing a call for future research from each that already existed in some way in the other field. This inspired me to act in a linking role between the two disciplines, with a unique capacity to translate and apply quantitative IE works into transition language and research with potential for impact in policymaking, decision-making, positioning, and applying a framework to the context.

2.3.4. Subjectivity, normativity, and scientific quality

All of my research was conducted as objectively as possible and in line with the Netherlands Code of Conduct for Research Integrity, which defines five principles of research integrity and 61 standards for good research practices and duties of care for the institutions. The Code of Conduct is the guiding principle for NWO's integrity policy, and it ensures that the Netherlands keeps up with international developments regarding research integrity. In practice, this means striving to maintain the virtues of honesty, scrupulousness, transparency, independence, and responsibility in each phase of the research process: design, conduct, reporting, assessment and peer review, and communication. This also translates to the call for institutions to provide a working environment that promotes and safeguards good research practices. They ensure that researchers can work in a safe, inclusive, and open environment where they feel responsible and accountable, can share concerns about dilemmas, and can discuss errors made without fearing the consequences (NWO, 2018). At DRIFT and in my PhD, I have indeed always had this important space to report results and discussions of my research as objectively as possible.

2.3.5. Methodological implications of axiology

As axiology often informs methodology, it is important to acknowledge that my axiological thinking related directly to the selection of appropriate methodologies and methods in my thesis. In terms of the value-oriented positioning of my work, I refer particularly to my desire for practice-related implications: that of a pragmatist's approach to research. Pragmatism involves research designs that incorporate operational decisions based on "what will work best" in finding answers for the questions under investigation, and this enables pragmatic researchers to conduct research in innovative and dynamic ways to find solutions to research problems (Kelly & Codeiro, 2020). Given the nature of transitions and the related need to explore and innovate, it was a structured, methodological, and deliberate choice to incorporate this pragmatic style of research design into my methodology. This allowed for more methodological flexibility in the design, creation, and testing of the CDMT (Chapter 5) and a more prospective approach to illustrating the CDMT through an application of the framework in France's wine sector (Chapter 6), due to the explorative nature of the works.

However, the first piece of my research, as detailed in Chapter 3, aligns with the explanatory goal and style of critical realism, in that I aimed to "explain processes by analyzing actions in the context of structures" (McDowall & Geels, 2017, p. 46). Through the semi-structured interviews I conducted with stakeholders from various pillars of society (with different perspectives on and relationships to the studied phenomenon

of the uptake of circular catering at multiple levels), my methodology aligned with that of a critical realist, wherein I "trace[d] processes and event chains [and] attempt[ed] to infer causal mechanisms and deeper structures" (ibid, p. 46). In this way, I aimed to offer insight on the underlying dynamics within a particular regime that could facilitate a condition for a transition to progress or occur, as a critical realist would. Yet, I also wove in principles of my pragmatist approach when arranging interviews in a highly selective way of decision-makers and movers directly related to the upscaling of circular catering to understand the different motives involved in people's actions in this specific situation. This combination of schools of thought influenced the methods used, including interviews, direct observation, and co-working, to uncover and assimilate information surrounding the phenomenon and investigate the "mechanisms" or principles that might have favorably influenced the outcome of this upscaling.

My institutional context at DRIFT and personal background has led me to value action-oriented and participatory methods. I valued meeting, co-working, interacting, and sharing knowledge back with participants while conducting my research, designed the methods so that results could be useful not only for furthering research or in other contexts, but could also feed directly back to the participants. This steered my action-oriented style of conducting semi-structured interviews from Chapter 3 and the design of the focus group workshops in Chapter 5. This design involved conducting two focus group workshops in the Netherlands, and then – based on my experience with the Dutch workshops and evaluation of and discussion surrounding the CDMT – I also designed similar international workshops. For these, I provided a reporting template to our international project partners to take on a similar approach in their context, where I guided them to invite a variety of stakeholders. The intention (and execution) was to create co-designing focus group workshops, rather than knowledge transfer focus group workshops. My action orientation was also related to my primary scientific paradigm of pragmatism. I particularly touched on the principle that "a pragmatic researcher seeks to transform a problem by investigating its complex interrelated elements in order to better understand the entire situation. The goal is to present alternatives and to take appropriate action" (Salkind, 2010, p. 1074). In Chapter 5, the CDMT is a visual presentation of alternatives embedding interrelated elements of a circular decision. It was also designed in particular to equip decision-makers with more information in this context, as well as act as a discussion tool between actors for circular decisions that involve more than one person to take a more highly desirable circular action together.

It is relevant to note that pragmatism is concerned with what "is", but also with what "might be". This orientation is towards prospective knowledge and not yet realized world

(Dewey, 1929). This orientation is why I valued the exploratory and prospective nature of the research design in Chapter 6, where I noted a shortcoming in sustainability of the French wine sector found during my literature review on the subject and discussed what it might look like to make use of the CDMT in this case and consider the potential of adopting circular economy in this sector.

2.4. METHODOLOGY

In my thesis, I utilized qualitative research methodologies, principally consisting of a case study (involving empirical work) and conceptual research (integrating principles of action research in the participatory elements of my methods). This generally qualitative approach was taken because qualitative research has been described in literature as more suitable for addressing the heterogeneous, contingent, and multi-level nature of socio-technical transitions (Andersson et al., 2014; McDowall & Geels, 2017), in addition to the shortage of available empirical quantitative data encountered and the explorative nature of my research questions. Furthermore, the policy and governance focus of my work, along with my analysis of paradoxes and value contestations in CE, may be better grasped with qualitative research (Dixon-Woods et al., 2007). My conceptual research included a synthesis of qualitative data gathered through interviews into a categorization of principles for potentially facilitating favorable conditions for upscaling of circular innovation (Chapter 3); the conceptualization of the Waste-Resource Paradox, its implications, and related dilemmas (Chapter 4); the basis for the content, conceptualization, and creation of the Circular Decision-Making Tree (Chapter 5); and the application of this framework for navigating circular decisions in the French wine sector's transition to a circular economy (Chapter 6).

This combination of qualitative and conceptual methods, which best fit some of my exploratory research, also fit with my ontological and epistemological positioning – in that the intended impact of my research was for both theory and practice. For my first paper publication (Chapter 3), I selected a case study methodology to unpack a phenomenon of key observable manifestation of a transition occurring in real time in the Netherlands. The single-case study design was informed by the aim of critical realism – to explain events in natural settings: "Critical realism can be used for research methods to explain outcomes and events in natural settings—pertaining to questions about how and why events or phenomena occur. From this approach, critical realism recognizes that interventions and systems consist of 'emergent mechanisms' that can explain the outcomes" (Sturgiss & Clark, 2020, p. 143). Drawing on the principles of a critical realist approach, I investigated the conditions surrounding how and why a circular niche service scaled to a national level. The case study was descriptive in

nature (Yin, 2009) and had an abductive orientation: i.e., the phenomenon occurred in real time, and the research question and hypothesis were built around why the phenomenon might have come to happen. By the abductive orientation to this analysis, I refer to a "qualitative data analysis approach aimed at theory construction [based on] cultivation of anomalous and surprising empirical findings" (Timmermans & Tavery, 2012, p. 169). This approach led to the 15 practices in Chapter 3, created from concept-driven coding of my interview transcriptions. My methods selected were also based on the critical realist ideas of Bhaksar (1978; 1998; 2014) – that evidence can come close to reality but is always a subjective account. For this reason, the empirical work within the case included direct and detailed observational evidence of the upscaling of a circular service across multiple levels and sectors of society in my empirical work – also including co-working and bilateral information exchange – and presented the resulting empirical data and the real-life context in which it occurred.

My multi-method research was situated in sustainability and transition science – of which action research is a relevant component. The pragmatist Herbert Blumer claims that "the essence of society lies in an ongoing process of action – not in a posited structure of relations. Without action, any structure of relations between people is meaningless. To be understood, a society must be seen and grasped in terms of the action that comprises it" (1966, p. 541). According to Dewey (1929), action is the way to change existence – and "to perform changes in desired ways, action must be guided by purpose and knowledge" (Goldkuhl, 2012, p. 139). In my work, I hoped both to glean principles and results from my work with transferability to other situations to create scientific relevance, as well as to offer a positive impact or takeaway for other actors taking part in the study. For example, during my empirical work of the case study at BlueCity010 (Chapter 3), in addition to direct participant observation, my research involved co-working with participants in the same physical space and object of study. Similarly, during international co-creative workshops which were designed for external validation of a decision-making framework model (Chapter 5), I also incorporated elements co-design with the transdisciplinary groups of participants from practice, consultancy, research, and the non-profit sector. Incorporating principles of action research is relevant to the transition to a CE for a variety of reasons: it increases the outreach through the involvement of other societal actors, it enables critical debates about CE, and it may be generative in itself in terms of finding solutions to overcome barriers to CE acceleration. It is for this reason that, in carrying out my conceptual or more traditional research and the case study, I drew on these pragmatist values to make the participatory elements more potentially transformative and action-oriented when possible.

2.5. METHODS & DATA SOURCES

In my methods, I made use of literature reviews as my baseline knowledge and first step, repeating in iterations throughout the thesis. In line with the protocol for systematic reviews described in Tranfield et al. (2003) and Briner and Denyer (2012), my literature reviews involved three main stages: the planning stage starting with a research question (which informed the searching and screening steps in the selection of articles); the conducting stage, data synthesis, analysis, and interpretation; and reporting findings as related to the research questions. These reviews included key scientific articles and foundational literature on transitions science and circular economy, EU policy documents and laws on circular economy roadmaps and implementations, legal documents, annual reports, press releases, policy documents, research reports, company websites, governmental websites, and academic sources such as books, journals, and conference proceedings. This served as the basis for my understanding of the scientific knowledge of both transition science and circular economy. Throughout my research, I paired this knowledge basis with other methods including semi-structured interviews, direct participant observation, co-working with participants, and international workshops with transdisciplinary groups.

In particular, my conceptual work first began with an extensive literature review surrounding sustainability transitions theory and circular economy. This contributed to my first paper, a descriptive case study of the phenomenon of a circular service being upscaled from a niche to a national level (Chapter 3). To build on this conceptual knowledge with empirical data, my local empirical work in Rotterdam included participant observation, co-working, and conducting interviews with actors and organizations from various sectors, pillars of society, and scales. I conducted participant observation to gain an understanding of the symbiotic nature of the involved entrepreneurs and other parties. Next, I conducted semi-structured face-to-face interviews of 1-2 hours on site at the interviewee's workplace, coded the transcriptions manually and thematically, and analyzed the results with members of a multinational catering company transitioning to be more circular, a currently circular catering company, and the Ministry of Infrastructure and Water Management of the Netherlands taking up circular catering. In this study, and more generally when engaging with stakeholders in participatory elements of my research, I tried to do so in an interactive way with bilateral information exchange.

This series of interviews and empirical investigations led me to observe 15 core generalizable principles for connecting niche and regime organizations and thought patterns (see Chapter 3 results) and further to observe what seemed to be an overuse of the word "circular" – increasing in frequency of use but decreasing in direct connection

to what would fit in a new paradigm of a fully operational circular economy. I was intrigued to pull at this thread further, and a clear societal paradox surfaced – notably present in the transition zone between the linear economy and circular economy regimes, in response to the new uncertainty surrounding the value of a material's potential second life. The deeper I delved into the (mis)use of the term "circular," the more innovations and business models I found that actually contradicted the meaning of a circular economy and had important, often undesirable, implications for social, environmental, economic, and legal dimensions of society (see Chapter 4 discussion).

When interpreting the results of Chapter 3, I chose to frame the results aligning with pragmatist Charles Sanders Peirce's conviction – to look at general long-term effects and experiences, not just short-term specific ones (Salkind, 2010) – by creating principles that I hoped could be generalizable and used in other, greater, distinct contexts than that of my case in the Netherlands. I adopted this same position in the following Chapter 4 on the Waste-Resource Paradox – examining the long-term consequences of interventions and circular innovations. In this chapter, I mirrored Peirce's positioning, by pointing out the currently largely overlooked important material, energy, economic, and social tensions related to the WRP in the transition to a circular economy: when circular innovations may seem to be sustainable in the short-term, but cause complications or rebound effects in the long-term.

Based on some of the threats from some dilemmas described, I hypothesized that these may be resulting in part due to a shortage of adequate decision-making tools in practice. In response, I devised what is my interpretation of the most essential information for actors with decision-making power that may aid in more directly contributing to the acceleration of the transition to a circular economy (see Chapter 5 for this logic, tool, and a detailed explanation thereof). Pragmatic studies often seek to understand the multiple factors involved in people's actions in a given situation (Salkind, 2010), and the method for designing the CDMT of Chapter 5 was created and designed based on a pragmatist approach: first conducting a literature review of circular economy, decision tools, waste hierarchies, and quantitative models stemming from industrial ecology, leading me to glean multiple key factors in people's actions in a given situation, i.e., when deciding on a circular innovation to support or scale up. To also address the key factors in people's decisions outside the circularity value, the CDMT includes links to other tools appropriate for factors that might be important: financial (e.g., cost-benefit analysis), cultural/social (e.g., principles from Chapter 3), and environmental (e.g., life cycle assessment). Because circular economy is also a part of broader EU goals and generally relevant on a conceptual, global level, I externally validated the CDMT through multiple focus group workshops with transdisciplinary participants in four countries

across three continents. This involved organizing workshops and group interviews in both the Global North and Global South: namely Brazil, South Africa, the Netherlands, and the United Kingdom, for feedback on the framework. In a pragmatist approach to the design of the CDMT, some potential complexity (involving other fields of study on the framework itself or other factors detailed in Chapter 5's appendix) was edited out to increase usability in practice. Afterwards, I used the tool developed in the Dutch context to a sector closely tied to my work before DRIFT: sustainability in the wine sector, here applied specifically to the French context (Chapter 6). To offer a more complete visual understanding of the steps, development, and outcomes of my thesis, the reader may refer to Figure 3:

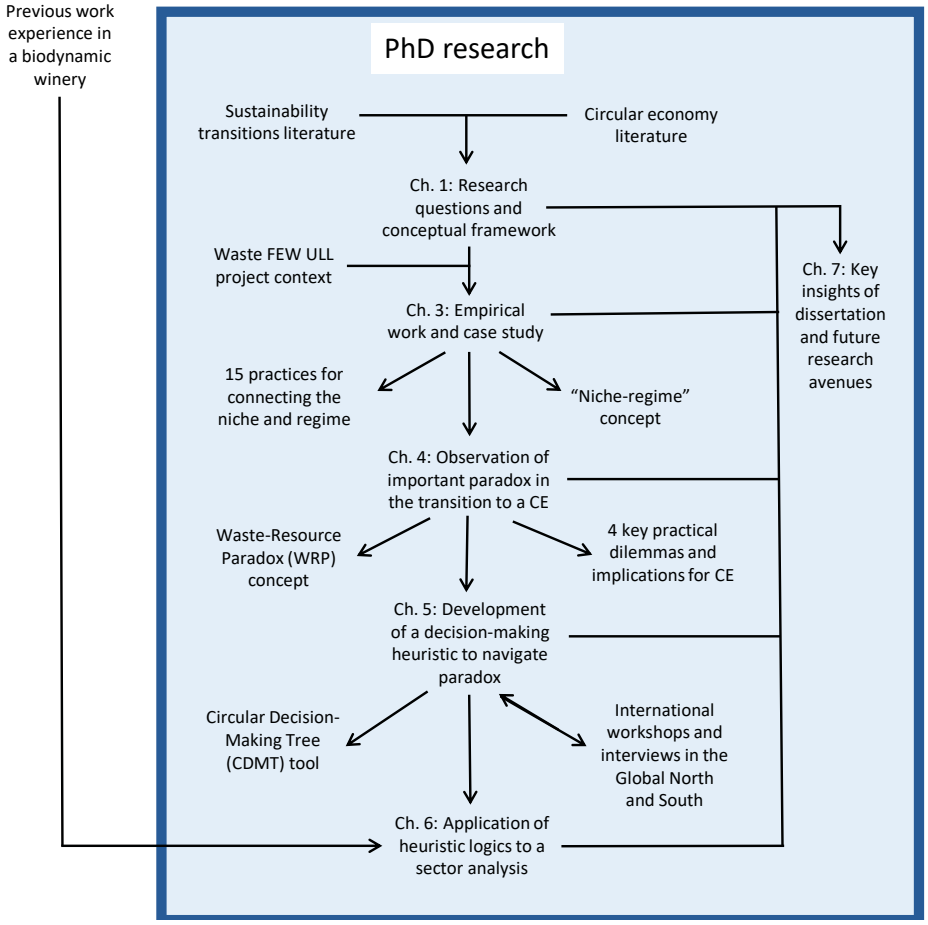


Figure 3. A simplified structuring of my thesis research process and outcomes.

The methodology and content of the four papers summarized here are offered in full in the following four chapters (3-6). In Chapter 3, I offer principles for connecting niche innovation to regime institutions, which is conceptually contributory but also practically applicable. In Chapter 4, I present a conceptual innovation that can also prove immediately relevant to decision-makers in practice. Chapter 5 presents a potential solution to the paradox described in the previous chapter through a decision-making framework that is designed to prioritize higher-quality circular innovations and to be applicable in practice, across many waste flows and in international settings. Finally, Chapter 6 is an illustrative application of this tool to a case, in an exploratory study inspired by experiences from practice.

2.6. REFERENCES

Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9-16.

Andersson, C., Törnberg, A., & Törnberg, P. (2014). Societal systems–complex or worse?. *Futures*, *63*, 145-157.

Bhaskar, R. (1978). On the possibility of social scientific knowledge and the limits of naturalism. *Journal for the Theory of social Behaviour*, *8*(1), 1-28.

Bhaskar, R. (1998). Philosophy and scientific realism.

Bhaskar, R. (2014). *The possibility of naturalism: A philosophical critique of the contemporary human sciences*. Routledge.

Blumer, H. (1966). Sociological implications of the thought of George Herbert Mead. *American journal of sociology*, *71*(5), 535-544.

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.

Dewey, J. (1929). The quest for certainty.

Dixon-Woods, M., Sutton, A., Shaw, R., Miller, T., Smith, J., Young, B., ... & Jones, D. (2007). Appraising qualitative research for inclusion in systematic reviews: a quantitative and qualitative comparison of three methods. *Journal of health services research & policy*, *12*(1), 42-47.

Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research policy*, *39*(4), 495-510.

Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. *European journal of information systems*, *21*(2), 135-146.

Greenhalgh, T., & Papoutsi, C. (2018). Studying complexity in health services research: desperately seeking an overdue paradigm shift. *BMC medicine*, *16*(1), 1-6.

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

Grix, J. (2002). Introducing students to the generic terminology of social research. *Politics*, *22*(3), 175-186.

Hebinck, A., Diercks, G., von Wirth, T., Beers, P. J., Barsties, L., Buchel, S., ... & Loorbach, D. (2022). An actionable understanding of societal transitions: the X-curve framework. *Sustainability Science*, 1-13.

Kelly, L. M., & Cordeiro, M. (2020). Three principles of pragmatism for research on organizational processes. *Methodological innovations*, *13*(2), 2059799120937242.

Killam, L. (2013). *Research terminology simplified: Paradigms, axiology, ontology, epistemology and methodology*. Laura Killam.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. sage.

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.

McDowall, W., & Geels, F. W. (2017). Ten challenges for computer models in transitions research: Commentary on Holtz et al. *Environmental Innovation and Societal Transitions*, *22*, 41-49.

NWO (Nederlandse Organisatie voor Wetenschappelijk Onderzoek). (2018). Accessed on 21 December 2021, from: https://www.nwo.nl/en/netherlands-code-conduct-research-integrity

Ponterotto, J. G. (2005). Qualitative research in counseling psychology: A primer on research paradigms and philosophy of science. *Journal of counseling psychology*, *52*(2), 126.

Rodrigo, D., Limaj, O., Janner, D., Etezadi, D., García de Abajo, F. J., Pruneri, V., & Altug, H. (2015). Mid-infrared plasmonic biosensing with graphene. *Science*, *349*(6244), 165-168.

Salkind, N. J. (Ed.). (2010). *Encyclopedia of research design* (Vol. 1). sage.

Sturgiss, E. A., & Clark, A. M. (2020). Using critical realism in primary care research: an overview of methods. *Family Practice*, *37*(1), 143-145.

Tashakkori, A., & Teddlie, C. (2010). Putting the human back in "human research methodology": The researcher in mixed methods research. *Journal of mixed methods research*, *4*(4), 271-277.

Timmermans, S., & Tavory, I. (2012). Theory construction in qualitative research: From grounded theory to abductive analysis. *Sociological theory*, *30*(3), 167-186.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207-222.

Wiek, A., & Lang, D. J. (2016). Transformational sustainability research methodology. In *Sustainability science* (pp. 31-41). Springer, Dordrecht.

Wittmayer, J. (2016). Transition management, action research and actor roles: understanding local sustainability transitions

Wittmayer, J. M., & Schäpke, N. (2014). Action, research and participation: roles of researchers in sustainability transitions. *Sustainability science*, *9*(4), 483-496.

Yin, R. K. (2009). *Case study research: Design and methods* (Vol. 5). sage.

Zhang, P., Zhang, L., Chang, Y., Xu, M., Hao, Y., Liang, S., ... & Wang, C. (2019). Food-energy-water (FEW) nexus for urban sustainability: A comprehensive review. *Resources, Conservation and Recycling*, *142*, 215-224.

Zolfagharian, M., Walrave, B., Raven, R., & Romme, A. G. L. (2019). Studying transitions: Past, present, and future. *Research Policy*, *48*(9), 103788.

3

THE DIFFUSION OF CIRCULAR SERVICES: TRANSFORMING THE DUTCH CATERING SECTOR

Alternative ways to provide services based on circular economy principles are facing the problem of diffusing beyond local experimentations in niches to become mainstream. This is the entry point for our case study examining niche experimentation in the form of circular catering as developed within the urban living lab BlueCity010 in Rotterdam, the Netherlands, and how it interacted with incumbent actors. This case sets itself against the background of the national policy program "Circular Netherlands in 2050" and larger socio-political efforts to accelerate the transition to a circular economy in the Netherlands. Through a stakeholder analysis and in-person interviews, qualitative data was extracted that helped to map the process of diffusion, the inherent power dynamics, and connecting mechanisms between niche and current regime actors. The results detail various manners through which niche and regime actors connect, including actions taken to facilitate the diffusion of circular catering and settings that created a favorable environment. Our findings also include quantitative values for indicators of success from a Dutch ministry (e.g., CO_2 emissions range, percent of animal protein, reduction of food waste), which appear in their very preliminary stage to be on track for meeting their circularity goals within catering. Our research offers novel empirical insights into how to increase and scale cleaner production practices towards a circular economy through circular startups, summarized into 15 observed principles for connecting and integrating niche innovations to incumbent practices. Lastly, these observed practices are discussed in connection to sustainability transitions and in terms of their potential generalizability to cleaner procurement.

Keywords: Food-energy-water nexus, circular economy, urban living lab, transitions, diffusion pathways, niche-regime interaction

This article is reproduced here as published in its original source:
Greer, R., von Wirth, T., & Loorbach, D. (2020). The diffusion of circular services: Transforming the Dutch catering sector. *Journal of Cleaner Production, 267,* 121906.

3.1. INTRODUCTION

Because of a prevalent view gaining traction that continuous optimization within a linear economy will not suffice for sustainable production and consumption patterns, progressively more actors are starting to pursue alternatives. Generally referred to as part of a *circular economy* (CE), these alternatives seek to radically reduce – or in the highest actualization, to eliminate entirely – the production of waste involved in consumption (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). Operating on this, scientists, enterprises, and decision-makers are opting to take and support steps that pursue a more systemic shift away from the current dominant system of business-as-usual to a circular economy (Ghisellini, Cialani, & Ulgiati, 2016). This implies an economy based on circular practices, wherein the reigning goal is not to incrementally reduce the environmental impact from products, but to radically shift to new systems of procurement, cleaner pipe, and end-of-life solutions that contribute to closed loops of materials and energy (Tukker, 2015). Within that context, the Dutch government has set an ambition for the Netherlands to become fully circular by 2050 (*Ministerie van Algemene Zaken*, 2019). To reach this goal, the focus lies first with transforming different pilot sectors – one including a new, circular form of catering. The Ministry's vision of circular catering has been defined to encompass: procurement (choosing products that apply circular principles), production (increasing recyclable bio-based raw materials for disposables, with as little mono-packaging as possible), business operations (minimally burdensome preparation methods and distribution processes), assortment choice (more vegetable proteins, preferably produced locally), and the use of residual flows (e.g., coffee grounds, tomato stems, beet pulp) (Heijink, 2019).

Catering and its related production and consumption practices are relevant aspects within the food system. Worldwide, around one-third of all food produced for human consumption is lost or wasted (FAO, 2011). This accounts for an estimated 8% of annual greenhouse gas emissions (CAIT, 2018). In response, research on sustainability issues in and circular approaches to catering has begun to emerge, including the role this industry could play in helping to reduce the high levels of food waste. For example, studies explored the gap between reported and actual food waste in Welsh hospital catering (Sonnino & McWilliam, 2011); the ambiguity in sustainability criteria definitions in Finnish food procurement was uncovered (Lehtinen, 2012); and the shaping of strategic procurement and consumption models in food and catering to reduce waste have been studied (Goggins, 2018). These studies have offered contributions for the identification and reduction of waste involved in catering, as well as ways to improve sustainable practices and procurement in this service model. However, what is lacking is an attempt to go beyond the sheer problem of understanding of food waste from

catering practices. Hence, in our study a transformative research lens is taken, building on transition and innovation theory. We will explore how an alternative catering model – made up of a collection of circular approaches – can be diffused and scaled up, to create more widespread and transformative impact.

In their overarching critique of current circular economy research, Kirchherr & van Santen (2019) observe the lack of empirical work on CE in existence, as well as the fact that CE work is by-and-large focused on manufacturing industries. Only 9% of articles focus on the service industries – which is problematic, because most GDP these days in many countries (70% in the European Union) stems from services (ibid). This makes evident the novelty of our work: studying CE implementation and scaling empirically, and particularly exploring a network of circular entrepreneurs that together offer a service. This is key to CE, because a new economy is not based on singular business models or circular products; rather, it largely encapsulates actor networks and services.

Within the Dutch study context, previous research addressed sustainable public procurement (Melissen & Reinders, 2012), and critical success factors in the maintenance of sustainable business models for small and medium-sized enterprises in the food and beverage industry (Long, Looijen, & Blok, 2018). However, literature surrounding the consideration of actor network effects, and in particular in the case of a governmental body's innovation adoption appears to be absent to date. In this paper, we focus on how circular catering diffused from an alternative niche into adoption by one of the national ministries, and the factors that played a role in this diffusion process.

3.1.1. The transition to a circular economy

There are many definitions and understandings of a circular economy. Some refer to closing and slowing loops (Bocken et al. 2017), and others call for the use of raw materials and energy through multiple phases (Yuan, Bi, & Moriguichi, 2006). While we agree with these principles adhering to a circular economy, the definition with which this research identifies most with, for its comprehensiveness in description of various levels and wider goals of CE, is that the one provided by Kirchherr, Reike, & Hekkert (2017, p. 229): "An economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production, distribution, and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial park) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity to the benefit of

current and future generations. It is enabled by novel business models and responsible consumers."

The concept of CE envelops resources, pricing, externalities, and closing loops, but it is also (on a grander scale) about changing economic (i.e., actor) relationships. The general challenge of CE is to deal with all materials through a process of *dematerialization, material substitution, and reuse of materials at the end of their life cycle*. This case study of a transition of services concerns the reduction and prevention of waste, shifting towards providing a different kind of service and embedded products.

Our study builds on the work of de Jesus & Mendonça (2018), who studied the drivers and barriers in eco-innovation related to circularity. We took their work a step further, asking: what might these drivers and barriers to a circular economy be if we examine not only a single innovation, but an entire service consisting of interdependent and interconnected circular innovations and innovators? In a related study, the research by Kirchherr et al. (2018) argued that cultural barriers are the main barriers to scaling circular startups. We set out to investigate if this was also the case in the Netherlands, particularly around catering services. Furthermore, we build on concepts from transition theory in order to understand the dynamics at play when alternative practices of a circular economy evolve and start to challenge existing catering practices. With that transition lens, we understand the current production of goods and waste as deeply embedded in societal cultures and practices, i.e., a "*regime*" (Kemp, Schot, & Hoogma, 1998). When referring to the regime, we mean incumbent thought patterns and dominant structures in society (Schot & Geels, 2008). These develop path-dependently and are locked-in because of embedded routines, vested interests, sunk costs, and institutionalized conditions (Arthur, 1989). *Niches*, in contrast, are experimental deviations from the norm that begin to emerge as a response to increasing pressures on the regime (Schot & Geels, 2007). Changing societal contexts, sustainability concerns, and geopolitics increasingly put pressure on incumbent regimes leading to internal tensions. Hypothetically, this pattern of external pressures and internal regime tensions creates the conditions for disruptive, non-linear regime change (Berkhout, Smith, & Stirling, 2004): a transition – in this case, from a linear to a circular economy.

This study builds mainly upon socio-institutional work on sustainability transitions (Loorbach, Frantzeskaki, & Avelino, 2017), that emphasizes the plural role of transformative agency and explores mechanisms that help guide and accelerate transitions. These mechanisms relate to new types of discourses, structures, and practices that develop gradually – but under specific conditions, can become relatively

rapidly mainstream and embedded social norms. Of particular interest is the idea that to support this shift, new collaborations between actors from niches and from a regime context might help to create such structural changes. As pressures increase, actors within the regime start to engage in the contribution to system transformation, becoming a "proactive incumbent" with a role in the potential phasing out of established institutions (Hengelaar, 2017). Similarly, niches that gain traction and support begin to form their own regimes (de Haan & Rogers, 2019).

We empirically explore how actors operating at a niche level engaged with actors operating at a regime level: sharing a common interest in developing circular catering, but each coming from very different contexts and following different strategies. The differences in language, capacities, networks, skills, and resources must be overcome through mechanisms for diffusion. Smith (2007) also studied the emergence of green niches, the tensions in incumbent regimes that develop and allow space for niches to form, and the processes by which these niche and regime elements interact. Because of his similar work on niche-regime interactions, we adapt his structuring of analytical foci to cluster and analyze our own results.

Based on the preceding concepts and context surrounding the case at hand, the following research questions about the uptake of a circular catering services guided our study. First, *what are the persistent sustainability problems in catering, and do they trigger regime destabilization?* Within that context, *what are drivers and barriers of multi-level and cross-scale interactions surrounding such innovation diffusion?* Understanding the favorable settings for and possible actions to take to bring together niche and regime elements around circular service innovation would allow us to help create, foster, and support connections between these two generally discrete levels of society. Secondly, *what key elements in the diffusion of a circular service can be observed, and can these be generalized across contexts to prime the conditions for a transition to occur? What is the role of emerging alternatives in a possible future transition?*

Our research adds to studies on the diffusion of a singular innovation – like spent coffee grounds reused as a resource (Matrapazi & Zabaniotou, 2020) – by analyzing the actor network effects in a service system comprised of multiple interrelated and interconnected circular innovations. We unpack a circular service with the lens of the food-energy-water (FEW) nexus, an approach addressing the cross-sectoral and inherently embedded connections between flows of three different sectors, previously considered almost exclusively within their own domains. Studying the case through this nexus lens allowed us to avoid leaving cross-over effects and indirect relationships ignored or overlooked: in comparison to studies such as Neto and Caldas (2018), which

reviewed EU schemes for insight into the use of green criteria in the public procurement of food products and catering services, but did not address the FEW nexus. Recent research by Henry and colleagues (2020) created a typology of five categorizations for 128 circular startups, showing that circular startups tend to embrace strategies corresponding to higher levels of circularity than those of incumbents, and circular startups can indeed make major contributions to transitioning towards CE, which helped structure the thinking of our work. Lastly, in contrast to the majority of current literature that examines circular startups from a bottom-up perspective, our study uniquely takes a perspective slanting towards the existing service functions among incumbent actors.

Our main objective was to analyze and unpack an empirical attempt at scaling a complex, radical alternative catering system aimed at the prevention of waste production and increase of efficiencies in the use of energy, water, and resources. Our case directly addresses practices of cleaner production in an international corporation, a governmental body, and an eco-system of startup entrepreneurs. By this, our work makes a novel contribution to the scientific debate about pathways to circularity by studying circular economy empirically and providing insights into the stakeholder interactions in and potential of upscaling an ecosystem of interrelated circular innovations that together comprise a service.

3.2. METHODS

3.2.1. Case study context

Circular services and innovations are still a niche, in that incumbent practices are still organized around linear models based on maximization of economic profits, often at the cost of large environmental impacts. Yet, there is a growing interest from incumbent regime actors to explore and proactively engage with such alternatives to help shift their business model, and increasing viable models are emerging (Bocken, De Pauw, Bakker, & van der Grinten, 2016).

This is the entry point for our case study in Rotterdam, the Netherlands, which examined the acceleration of niche experimentation and connections made with current regime actors in the catering context. It is an empirical case of a regime under transition pressure, within the scope of circular economy. The concept of circular catering emerged at a niche level and was carried out in a proof-of-concept through a network of circular entrepreneurs at Blue City (BC), an Urban Living Lab (ULL) in the city of Rotterdam. At Blue City, spent coffee grounds on campus are not directly thrown away, but rather, used to grow oyster mushrooms by an on-site startup, which in turn

are used to make a vegetarian substitute of a traditional Dutch bar snack by another BC entrepreneur. An in-house microbrewery producing beer creates a residual stream of brewery grain, not dumped but instead used as an ingredient by another local startup to make bread and cookies for the catering service.

In parallel, the Dutch Ministry of Internal Affairs issued a mandate to the Dutch Ministry of Infrastructure and Water Management (*Rijkswaterstaat [RWS]*) to convert all catering units in 16 different locations to a circular alternative from the current linear catering, in an effort to help "change the system" and lead a transformation towards circular initiatives for the country from the inside out. The exact system from BC was not upscaled directly at the ministry, but it offered a space for learning and showcasing how such a model could work.

3.2.2. Empirical procedure

The goal of our approach was to extract qualitative data to understand and describe how the circular catering services developed and fostered in a niche environment connected to, interacted with, and emerged at the regime level. A triangulation of a literature study, actor analysis, and qualitative interviews was carried out to systematically address the guiding research questions for a single case study.

A single case study approach was the preferred approach here, because it provides an opportunity for the researcher to gain a deep holistic view of the research problem, and facilitates describing, understanding, and explaining a research problem or situation (Baxter & Jack, 2008). Because depth achieved through a case study normally must be sacrificed in a comparative study – and the opportunities to study the degree of novelty of the diffusion process of a full circular service are still very rare – we selected this methodology to create the foundation for a scientific understanding of the phenomenon.

A thorough literature review was conducted on niche-regime interactions, augmented by a review of studies on the circular economy, its application, and its potential as a large-scale alternative to the incumbent linear economy. Next, a stakeholder analysis was conducted to identify relevant and prominent actors within the field of circular economy in the Dutch case context, to explore the complex web of loyalties, interests, influence, and alignment of key players around the issue. An initial list of stakeholders was created for the case study region, following the stakeholder analysis technique by Bryson (2004). Per this approach, we compiled a list of key stakeholders considered for interviews on two levels. First, we assessed broadly the relevant actors at the FEW nexus in the Netherlands. Second, we unpacked this further specifically for this case

of circular catering, for a more fine-grained actor analysis. The actors considered were categorized into three size groups (large, medium, small), based on both the size of the organization and their agency. An assessment of the most accessible and most influential was made; these stakeholders were invited for an interview.

Key actors pertaining to four societal domains – government, multinational corporate, intermediary platform, and startup entrepreneurs – were selected to understand the niche-regime interaction from different perspectives. Eleven in-person interviews were conducted within the time frame of eight months, and all lasted between one and two hours. For transparency and comparability, individuals were asked to define "circular" – as a descriptor for a type of entrepreneur, business model, catering scheme, or economy – and how they learned of the concept. Among other details, each interviewee was asked to describe their motivation behind the uptake of an alternative catering model and their experience in the process of implementation, the drivers and barriers of adopting circular catering in their organization, what helped accelerate the transition within their system, and what was learned from the process.

These interviews were transcribed on-site and recorded for record-keeping; they were then analyzed through a modified template analysis technique (King, 2012) to bring to light clusters of information and commonalities and/or distinctions within each cluster across the different stakeholders. Interview transcripts were labeled, and we organized the qualitative data to identify different themes and the relationships between them. Our manual concept-driven coding process revealed collections of data surrounding the drivers and barriers in the process of upscaling, power dynamics, diffusion pathways, connection-making, and trust-building bridging the niche and regime.

In order to analyze the qualitative data from the series of interviews, we adapted the theoretical framework developed by Smith (2007), structuring niche-regime interactions into "lessons learned" and "practices observed". However, his earlier approach to studying these interactions slanted towards a niche perspective; whereas, our study's lens places more emphasis on the dynamics happening at the regime level. Based on this, we removed the category "niche expectations" for our interviews and data analysis, adapted "technical configurations" to "socio-technical configurations" to accommodate the broader range of coupled socio-technical configuration in society that we include, and we added "observed practices" as a way to further typify our findings of already manifesting new practices.

3.3. RESULTS & DISCUSSION

3.3.1. Political and national contextualization

A group of innovative agents within a regime organization introduced the idea of circular catering at a high governmental level. This transformative idea was legitimized by and implemented because of an assignment from the Dutch Ministry of Internal Affairs. It makes an interesting case because the *Rijkswaterstaat (RWS)* had not yet heard of circular catering when the internal attention for the theme began – they only received an assignment to transform their catering model from linear to circular and implement this in practice across physical building locations. The breaking down of linear catering at RWS began with a market consultation in August 2017 and reached a near phase out within two years. The climate innovation funding from the Ministry of Foreign Affairs allocated grants for research into circular solutions (among others, e.g., the Dutch Fund for Climate and Development) was cited as a key contributor for the progression of their transition.

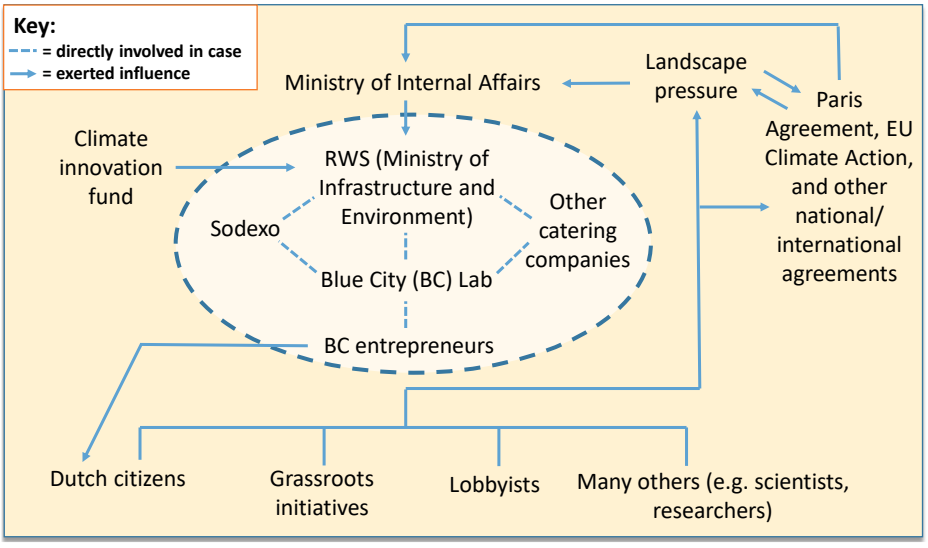


Figure 4: Empirical context of actors developing circular catering

Because of this organizational and structural support from the government, companies were strongly motivated by the possibility of a large monetary win to take up circular catering. This created a recognizable shift in the market, as a wide-spread demand for knowledge and innovation grew to meet the requirements of the tender competition. Figure 4 below gives an illustration of the broader context within which organizations that develop circular catering operate. In this paper, we try to unpack the interactions between these actors within this broader societal context.

Figure 4 illustrates the empirical context of external pressures exerted, related to the transformative case studied. The dashed circle indicates the organizations and actors directly involved in our study, inside their greater empirical context. Solid lines with arrows between actors indicate a directional relationship of exertion of influence, e.g., the BC entrepreneurs who host educational tours and interactive events to actively involve Dutch citizens, or the current landscape pressure which played a role in propelling the Ministry of Internal Affairs to start valuing circularity, who then in turn issued a mandate for the RWS to adopt circular catering. The dashed lines inside the oval indicate an interaction observed between actors studied directly in the case, e.g., Sodexo's partnership with BC – the former exchanging their broader network and connections for circular consulting and advisory work from the latter – or RWS issuing a tender that motivated catering companies including Sodexo to invest in knowledge and development of circular catering, modeled by Blue City. By examining the interactions between these actors within the oval sketched, we see immense complexity in their relationships. These interactions cannot be simplified into a single direction, so these relationships are illustrated with a line rather than an arrow. Further examples of our empirical findings are expounded upon in Section 3.2.

3.3.2. Empirical data and interview results

Various manners by which a transition to a circular service became further diffused are deconstructed below, based on the qualitative results of the various interviews conducted. The following mechanisms for bridging connections between niche and regime actors and organizations were unveiled – along with actions and settings that allowed for the observed destabilization of the regime and acceleration of niche alternatives – in the empirical case of circular catering in the Netherlands:

Table 2: Circular catering case study analysis

Analytical category	Observed practices	Illustrative examples
Learning		
1st order lessons about socio-technical performance	Assessing and creating awareness	External consulting for identification + measurement of waste streams Technology for waste assessment, e.g., Waste Watch "Circular scan" measuring and reporting back to landlord Menu selection based on life cycle analyses
2nd order lessons reflecting upon framing assumptions	Acting on assessment	Innovate ways to reduce resource input for processes, based on heavily disposed of materials calculated by e.g., Waste Watch
		Finding a new uses for top three company wastes identified in the "Material Passport"
Institutional embedding		
Socio-technical configurations	Forming and utilizing testing spaces	Space for proof of concept of circular catering Testing new sustainable marketing techniques in certain offices; at university canteens Non-monetary exchange to experiment for mutually beneficial solutions
Social network formation	Forming common goal-oriented coalitions	National and international initiatives, e.g., Plastic Pact, INNO9 projects Co-created contract between business peers with clear circular objectives Collaboration through existing personal relationships between actors Internal material exchange in business ecosystem
	Sharing places for niche-regime interactions	Initial investment in establishing ULL and other places Integration of outside niche thought through new hiring positions
Regime tensions		
The form in which environmental pressure is articulated/ relieved	Involving links up and down the value chain	Logistics partners, manufacturers, suppliers, and consumers of office canteen and event catering Instant delivery of additional food needed for receptions Involving and educating within value chain, e.g., *Verspillingsfabriek*, *Kromkommer,* and Instock Creating new contracts and negotiations, incorporating innovative procurement
	Influencing top-down / creating pressure	Higher ministry commissioning sector mandate in other national ministries High-agency governmental body issuing tender, with qualifying prerequisite of circular catering offered Politicians spearheading
	Empowering actors to pursue alternative sustainable pathways	Peer support fostered in daily work environment Government funding for large-scale experimentation in sustainability, e.g., *Klimaatenvelop* Awareness-raising and knowledge within government City government initiatives for financial subsidy and program acceleration

Table 2: (Continued)

Analytical category	Observed practices	Illustrative examples
	Enabling "just-right" size of circular venture	Catering tender small enough to de-incentivize legal instigation, yet large enough to make an impact
	Forming influential and informative narratives	Embodying and exemplifying mission and sustainability values (through steps towards circular services) Education and behavior change in staff through story telling Facility tours with embedded narratives
Niche-regime links		
Translating sustainability problems/solutions	Connecting platform/third-party facilitator	External "circular resource coach", internal "circular ambassador program" Green offices, universities as connectors Platform bridging niche and regime, and connecting peers Third-party oversight and facilitation connecting actors
	Matching of niche maturation with regime interest	Innovative niche startups must be ready for regime uptake (in preparedness of the business model and product/service), at the same time that a regime actor or organization is open to an innovative solution Appoint or utilize an internal or external actor designated specifically to match niche maturation (finding circular startups ready for scaling) with regime readiness
	Incentivizing competitions for solutions	External innovation challenges, e.g., Circular Challenge, Plastics Design Challenge: solution for food-related plastic waste streams of private and public regime-level organizations Internal innovation challenges → Incentivize win through collegial buzz, travel prize, money for idea implementation, and recognition
Adapting lessons	Co-creating solutions involving multi-level and cross-scale actors	Co-creation and interactive workshops with companies and universities, e.g., Future Food Lab at Utrecht University, Food Waste Workshop at Wageningen University Collaboration between competitors Open-source/sharing of information Circular catering transition team in company
Altering contexts	Improving the accessibility of wastes as resources	Possibility to use surplus supermarket food already classified as "waste" Spilled, imperfect, or pieces of food unfit for consumption to be utilized in another form Platform for trading waste streams, e.g., Excess Materials Exchange

One pathway for innovation diffusion is by connecting niche ideas to regime organizations. In the following text, we describe more in-depth the empirically observed practices and illustrative examples of such pathways for the diffusion of circular catering, as listed in Table 2.

3.3.2.1. Learning

The higher-level sustainability strategy connected to the business structure and culture is highly malleable according to human influence; the interview data indicated a need for learning, awareness, and favorable narratives to positively influence adoption by management. It was considered risky by some to pursue a circular catering model, but the government's innovative attitude steered them away from traditional procurement towards investment in sustainability. The same principle of openness can be applied in human resources: hiring minds that foster and create fresh ideas and innovation at the organization.

Many scholars also argue that universities must assume a role in the age of climate change because of their mission (Bardaglio & Putman, 2009); have a tremendous potential to transform the interface between science and society (Whitmer et al., 2010); and that these partnerships between higher education and the community can be used to promote urban sustainability (Molnar, Ritz, Heller, & Solecki, 2010). Universities can play a role in ULLs, giving keynotes and speaking truth to power. University initiatives to co-design and co-produce urban sustainability can potentially provide opportunities for strategic collaboration across differing sectors of the university and institutions, linking global level research and knowledge to place- and stakeholder-specific contexts and implementation efforts at the local or regional scale (Trencher et al., 2014). Yet, engagement and learning on CE is not yet commonly institutionalized or structured at universities; this asks for additional capacity building for circularity and effects which are not a part of academic and higher education programs. For this reason, researchers such as Kirchherr & Piscicelli (2019) propose a structured education for the circular economy (ECE). We would also recommend that CE themes be explicitly formalized in higher education programs to aid in learning and addressing barriers.

3.3.2.2. Institutional embedding

ULLs allow a physical space for experimentation, valuable for allowing regime actors to become aware of, acquire knowledge about, and have a tangible proof of concept of the processes, symbioses, and nuances related to the realization of circular catering as a service. Testing spaces also allowed regime-level organizations too large to make a body-wide change at once the chance to experiment in a small space and trial-run a circular solution with potential to be scaled to the whole organization. This finding supports

recent scientific claims that ULLs are viable platforms for experimental governance across sectors, reaching beyond niche-regime boundaries (von Wirth, Fuenfschilling, Frantzeskaki, & Coenen, 2019). The national strategy was an important factor for nearly all actors, directly or indirectly; it provided safety in terms of investments and pilots by reducing risk. This relates to the work of Kirchherr et al. (2018), who argued that cultural barriers are the main barriers to scaling circular startups; we observed conversely that political support and stimulation can be one of the main drivers for scaling circular innovation.

General drivers and barriers to niche diffusion have been addressed in literature, but they miss a level of specificity particularly concerning the role of network effects in innovation diffusion, e.g., changes in procurement systems, interacting network pieces, and peer pressure. The common goal building inherent in a contract between multiple businesses created a mutual understanding and agreed upon vision across peers, e.g., the Plastic Pact, signed by Sodexo and other large organizations: upheld between the government and corporations collectively obligating them to contribute to overall waste reduction. Additionally, an existing personal relationship between members of the connecting niche and regime organizations set a pre-established trust. It paved interconnections and actor networks that facilitated the spreading of ideas, concepts, and lessons on the diffusion of circular innovations; furthermore, it allowed for an internal exchange to avoid labels, relieving paperwork and bureaucracy.

3.3.2.3. Regime tensions

Connections via the value chain allow key players to push certain other actors in the chain. For example, it is an institutionalized rule within Blue City Lab to consider procurement efforts, meaning that all their office suppliers must value and implement sustainable practices to continue business. Similarly, any company applying to win the Ministry's tender must meet the minimum circularity guidelines for eligibility, forcing companies to rise to a higher standard and pressure their second-order suppliers to do the same. In the case of a multi-national catering company, incentives around sustainability were integrated in contracts to make the progression towards circularity more economically viable. Their position as a global organization allowed more room for negotiating power in contracts, and afforded them more reach to startups, both facilitating the diffusion of circular catering practices.

The Climate Innovation Grant awarded by the national government allowed regime-niches to emerge by providing frontrunners in incumbent regime organizations the financial creative space to innovate and experiment with niche concepts. The financial accessibility of innovation funding and entrepreneurial grants from the

Dutch government fosters sustainable startups and gives means for the creation and acceleration of innovation diffusion. Similarly, the RWS received money from the *Klimaatenvelop*, a funding agency with temporary money for research on how to make improvements in climate projects, which allowed them to experiment with circular catering.

A mandate from a higher ministry to adopt circular catering eliminated time, uncertainty, and dispute about the way to move forward. Having pre-established/non-negotiable collective goal aided in streamlining the progress by jumping immediately to planning for action in the switch to circularity in this sector. The role of narratives may have been an influencing factor in the top-down mandate being received positively and willingly. Rather than positing it as an autocratic governmental body forcing unwilling participants to incorporate sustainable practices, it was described as a collaborative co-implementation of circular actions towards a common goal. This created a general mindset of acceptance of the goal, and furthermore, personal belief in the importance, urgency, and benefits of the actions taken, aiding in the acceptance and uptake of a transformational catering model. From a bottom-up perspective, narratives can also help the public learn through preaching and demonstration. Tours of the ULL showcasing circular catering sparked interest and action in visitors.

3.3.2.4. Niche-regime links

Niche knowledge was received and symbiotically exchanged for expansion, venture capital, and/or global network contacts from the multinational corporation – resulting in mutually beneficial outcomes and further emergence of circular innovation. Public events – such as innovation challenges – served as learning spaces for incumbent regime actors (including average citizens) to acquire knowledge about circular innovations, a space for exposure of circular entrepreneurs, and physical platform for connecting. This engaged regime actors while empowering niche innovators, providing space for creation, diffusion, and support. Internal and external competitions offered another novel pathway for circular innovation diffusion as a cross-sector and cross-societal domain innovation platform, while also allowing for collaborations between actors to be developed. Similarly, volunteer opportunities integrated actors with niche thought into the dominant thought pattern at the regime level, making breakdown possible from the inside out.

Co-creation of solutions between actors of multiple levels of governance was seen to be successful in idea creation and solution pathway development, because it involved co-design and co-visioning between actors across multiple sectors. At the Ministry, the circular catering team was made up of a variety of actors to co-create contracts,

including internal and external advisors and experts – also creating a shared sense of responsibility. University groups served to bridge actor types and facilitate or participate in the co-creation.

Two unique startups at the ULL caught regime interest; one had a developed business model, while the other was not prepared to scale up. A third had a viable business case but did not capture regime interest and therefore stayed at the niche level. It was observed that two critical timelines must align serendipitously: an intersection of niche maturation and regime receptivity. A later interview added that having a designated person to take on the role or responsibility of being the "matchmaker" was key in capitalizing on naturally aligning timelines, scouting disruptive ideas and models, to match with current business needs. As an example, a "Circular Ambassador" program, with 5-6 business experts collecting best practices in circular catering from all around the country, was a successful example of a proactive way of institutionalizing insights in circular practices at a corporation's headquarters. An online presence also contributed to the coming together of previously unconnected actors and organizations, and thereby, to the diffusion of circular practices.

This niche-regime connection became more complex, however, when regulations impeded the exchange of materials. For example, the legal definition of waste in the Netherlands created undesired bureaucracy in the protocol for the procedure of selling, exchanging, or even giving away food – giving niche innovators less access to material for developing circular food solutions. This same principle also led to a logistics inefficiency in the case studied: a company's top waste stream was orange peels. Because they were strictly considered waste, they had to be disposed of as such. Thus, a truck delivered food to the building and then left empty, while another empty truck drove to the company site to then pick up the orange peels for disposal. Because of the characterization of the orange peels as a waste rather than a food, every delivery like this one requires two superfluous trips, compared to if they were legally permitted to be transported in the same truck.

3.3.3. Validity and intended impact

To monitor the effects of adopting circular catering, the RWS developed several key performance indicator (KPI) sets measuring: CO_2 emissions range, percent of animal protein, reduction of unsustainable single packaging, increased use of return packaging, and reduction of and reporting about food waste. Of these KPIs, the following quantitative effects were measured at RWS and reported by the circular caterer in relation to their initial annual goals, after 3 months' introduction of the circular catering concept:

- CO_2 footprint (Scope 3 measurement on food and drinks): Reduction of 19,260 kg CO_2-eq.
  - Goal after 12 months: Reduction of 53,930 kg CO_2-eq.
- Protein shift: Reduction from 67% animal protein to 65% animal protein.
  - Goal after 12 months: Reduction to 50% animal protein.
- Food waste in kitchen and banqueting: Net reduction met.
  - It increased 1.15% due to client wishes to open the restaurant in the Christmas vacation.
  - Nominal week food waste was about 1.5% lower than at the start of the contract.
  - Goal after 12 months: Reduction of 0.27%.
- Percentage of products with sustainability certificate: Increase of 0.9%.
  - Goal after 12 months: Increase of 1.5%.

Because the implementation at RWS is still so new, only one set of quarterly indicator measurements have been recorded to date. From this very preliminary data, it appears they are on track to successfully meet their yearly targets; however, it would be unwise to extrapolate this and make assertions about what will or will not happen in the future. Examining the progress (or lack thereof) in these KPIs would make an excellent starting point for future research, building on our study.

3.4. CONCLUDING REMARKS

This case raises questions on dynamics between the niche and regime levels in the context of a transition to a circular catering sector. It helps to understand the drivers and barriers of the emergence of a *niche-regime*: when a collection of niche actors and businesses with like-minded thoughts, values, and objectives start to form their own regime with a collective understanding and a common goal (de Haan & Rogers, 2019). We examined how this connected to a *regime-niche*: a small niche questioning business-as-usual within its respective regime context, open to and seeking radical change. In this paper, we have identified the dynamics and dialectics between these two entities. This is relevant to science, society, and policy, because they could provide clues for transitions in general on how to overcome the divide between levels of niche and regime.

Drivers for circular innovation uptake and diffusion at a service level included market pressure and peer competition, meeting a growing demand for sustainable alternatives and products, a mandate from a higher-level institute, upholding international treaties, entering climate agreements, contracts negotiated to financially or socially incentivize sustainable alternatives, (inter)national competitions, and a platform for communication that engaged emerging niche innovations with regime organizations. However, regime-

level organizations should thoughtfully consider the size of their ambition; when too radical or expansive, it may lead to backlash – when quick results do not materialize and setbacks are encountered. The tender put forth by RWS would award the winner all of the catering and restaurant businesses within 16 different building locations of the ministry for years, a volume that drove unsuccessful catering companies to wager fees in court, hoping to legally overturn the decision and win the new business and revenue streams.

This research constitutes the first study of its kind, examining the scaling of circular economy at a service level through a network of circular startups. It covered a specific case in which the circumstances were such that a live, physical proof-of-concept on how waste and resource flows could be connected between businesses to form a circular catering model emerged; this idea caught the interest of RWS, a regime-level governing body which then issued a tender to contract a circular caterer many building locations and incited financial incentive for incumbent catering companies to begin learning about and taking up such a circular practice.

We believe our results also may be of global relevance, because we hypothesize that these conditions would also facilitate the furthering of a transition in another industrial, cultural, or political context. We speculate that some of the observed principles in cleaner catering would be interesting for other sectors, considering what would be needed for a multi-industry transition to CE. For example, size and ambition of a tender to adopt a radical innovation would likely be key in another sector as well. Additionally, we hypothesize that awareness-raising, testing spaces, common goal-oriented agreements, co-creation, university partnerships, and connecting platforms could also be tools for scaling CE through circular startups in sectors outside of catering. Thus, it would be very valuable for future researchers to study and compare additional similar cases.

A future cross-case comparison applying our approach to another economy would make an interesting addition to the results of this first study uncovering the system dynamics involved in scaling a circular service. Future research may further unpack some of the observed practices and settings and test these insights in a new, distinct context to broaden empirical support across sectors and countries in the advancement towards the solidification of universal critical elements; the results of this study may provide important insights into principles that are more generally relevant for transitions and the governance thereof.

3.5. APPENDICES

Table 3: List of interviewees and role

Source	Role	Date	Societal domain
BC general manager	Project coordinator and managing director	2/4/19	Connecting platform
Sodexo innovation manager	Lead of innovation team: creating, capturing, and taking up new innovations at Sodexo	30/7/19	Multi-national private corporation
BC communications officer	Interacts with external organizations, bridging gap	22/1/19	Connecting platform
FnF founder	An entrepreneur creating new uses for otherwise disposed foods; also partially in charge of catering procurement at BC	10/4/19	Entrepreneur
BC office manager	Orders and organizes office and its supplies	20/3/19	Connecting platform
Sodexo business manager	In charge of internal and external business affairs and relations	30/7/19	Multi-national private corporation
RWS category manager: catering	In charge of catering procurement, tender issuing, and change management	27/3/19	Public governing body
Impact Express co-founder	Studio co-lead with the aim of creating societal impact; works closely with BC	10/4/19	Private local organization
Fruit Leather co-founder 1 & 2	Two entrepreneurs using tarnished fruit to create leather-like products	16/1/19	Entrepreneur
RWS procurement officer	Works in national and international contexts to change procurement models and value chains to become more circular	5/12/18	Public governing body

Table 4: Additional documents reviewed

Source	Content	Link (where applicable)
Document: "A Circular Economy in the Netherlands by 2050: Government-wide Programme for a Circular Economy"	National vision, interventions, innovative financing, and priorities in CE	https://www.government.nl/topics/circular-economy/accelerating-the-transition-to-a-circular-economy
Green Deal Circulair Inkopen (GDCI)	Circular procurement goals	https://www.gdci.nl/
Document: "RWS Vision and action plan towards a circular catering category"	Setting of the circular catering tender and concrete steps for reaching their goal	Document shared via email
Nederland Circulair 2050 from the *Rijksoverheid*	Dutch national circularity goals	https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050
Blue City website, internal documents, tours, and co-working	Intimate knowledge about inner workings of Blue City 010 and circular business models of startups	https://www.bluecity.nl/
Book: *Following-up on opportunities for a circular economy: better data for robust policy making*	Definitions of circular economy, related indicators and monitoring, and policy implications	Report number: TNO 2019 R11712
CAIT (Climate Analysis Indicators Tool)	Emissions related to food waste	http://cait.wri.org/historical
FAO (Food and Agriculture Organization of the United Nations)	Global food losses and food waste	ISBN 978-92-5-107205-9
Ellen MacArthur Foundation	Case studies and conceptualizations	https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy
Nederland Circulair Versnellingshuis	Acceleration pathways for circular startups	https://versnellingshuisce.nl/
Platform for Accelerating the Circular Economy (PACE)	The role of the Netherlands in accelerating a circular economy, in relation to other global leaders	https://pacecircular.org/

3.6. REFERENCES

Arthur, W. B. (1989). Competing technologies, increasing returns, and lock-in by historical events. *The economic journal, 99*(394), 116-131.

Bardaglio, P. W., & Putman, A. (2009). *Boldly sustainable: Hope and opportunity for higher education in the age of climate change*. NACUBO.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report 13 (4),* 544-559.

Berkhout, F., Smith, A., & Stirling, A. (2004). Socio-technological regimes and transition contexts. *System innovation and the transition to sustainability: Theory, evidence and policy*, 44(106), 48-75.

Bocken, N. M., De Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33*(5), 308-320.

Bocken, N. M., Olivetti, E. A., Cullen, J. M., Potting, J., & Lifset, R. (2017). Taking the circularity to the next level: a special issue on the circular economy. *Journal of Industrial Ecology*, *21*(3), 476-482.

Bryson, J. M. (2004). What to do when stakeholders matter: stakeholder identification and analysis techniques. *Public management review*, 6(1), 21-53.

CAIT (Climate Analysis Indicators Tool). (2018). *Historical Emissions*. http://cait.wri.org/historical. Accessed February 6, 2018.

de Haan, F. J., & Rogers, B. C. (2019). The Multi-Pattern Approach for Systematic Analysis of Transition Pathways. *Sustainability*, *11*(2), 318.

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

FAO (Food and Agriculture Organization of the United Nations). (2011). *Global Food Losses and Food Waste – Extent, Causes and Prevention*. Rome: FAO.

Geels, F., & Raven, R. (2006). Non-linearity and expectations in niche-development trajectories: ups and downs in Dutch biogas development (1973–2003). *Technology Analysis & Strategic Management, 18*(3-4), 375-392.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy*, 36(3), 399-417.

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm?. *Journal of Cleaner Production*, *143*, 757-768.

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.

Goggins, G. (2018). Developing a sustainable food strategy for large organizations: The importance of context in shaping procurement and consumption practices. *Business Strategy and the Environment, 27*(7), 838-848.

Heijink, Rob. (2019, March 15). *Naar een Circulaire Categorie Catering: Een visie en actieplan voor het circulair maken van de categorie* (Version 4.5).

Henry, M., Bauwens, T., Hekkert, M., & Kirchherr, J. (2020). A typology of circular start-ups: Analysis of 128 circular business models. *Journal of Cleaner Production*, *245*, 118528.

Hengelaar, G. (2017). *The Proactive Incumbent: Holy grail or hidden gem?: Investigating whether the Dutch electricity sector can overcome the incumbent's curse and lead the sustainability transition* (No. EPS-2016-ERIM Series 438-ORG).

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technology analysis & strategic management, 10*(2), 175-198.

King, N. (2012). Doing template analysis. *Qualitative organizational research: Core methods and current challenges*, *426*, 77-101.

Kirchherr, J., & Piscicelli, L. (2019). Towards an education for the circular economy (ECE): five teaching principles and a case study. *Resources, Conservation and Recycling*, *150*, 104406.

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

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

Kirchherr, J., & van Santen, R. (2019). Research on the circular economy: A critique of the field. *Resources, Conservation and Recycling*, *151*.

Lehtinen, U. (2012). Sustainability and local food procurement: a case study of Finnish public catering. *British Food Journal, 114*(8), 1053-1071.

Long, T. B., Looijen, A., & Blok, V. (2018). Critical success factors for the transition to business models for sustainability in the food and beverage industry in the Netherlands. *Journal of Cleaner Production, 175*, 82-95.

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.

Matrapazi, V. K., & Zabaniotou, A. (2020). Experimental and feasibility study of spent coffee grounds upscaling via pyrolysis towards proposing an eco-social innovation circular economy solution. *Science of The Total Environment*, 137316.

Melissen, F., & Reinders, H. (2012). A reflection on the Dutch sustainable public procurement programme. *Journal of Integrative Environmental Sciences, 9*(1), 27-36.

Ministerie van Algemene Zaken. (2019, August 30). *Circulaire economie*. Retrieved October 16, 2019, from https://www.rijksoverheid.nl/onderwerpen/circulaire-economie.

Molnar, C., Ritz, T., Heller, B., & Solecki, W. (2010). Using higher education-community partnerships to promote urban sustainability. *Environment*, *53*(1), 18-28.

Neto, B., & Caldas, M. G. (2018). The use of green criteria in the public procurement of food products and catering services: a review of EU schemes. *Environment, development and sustainability, 20*(5), 1905-1933.

Rietveld, E., Stegeman, H., Tukker, A., Keijser, E. E., Hauck, M., Poliakov, E. V., & Bastein, A. G. T. M. (2019). Following-up on opportunities for a circular economy: better data for robust policy making.

Rotmans, J., & Loorbach, D. (2010). Towards a better understanding of transitions and their governance. A systemic and reflexive approach. *Transitions to sustainable development. New directions in the study of long term transformative change*, 105-198.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology analysis & strategic management, 20*(5), 537-554.

Smith, A. (2007). Translating sustainabilities between green niches and socio-technical regimes. *Technology analysis & strategic management, 19*(4), 427-450.

Sonnino, R., & McWilliam, S. (2011). Food waste, catering practices and public procurement: A case study of hospital food systems in Wales. *Food Policy, 36*(6), 823-829

Trencher, G., Yarime, M., & Kharrazi, A. (2013). Co-creating sustainability: cross-sector university collaborations for driving sustainable urban transformations. *Journal of Cleaner Production*, *50*, 40-55.

Trencher, G., Bai, X., Evans, J., McCormick, K., & Yarime, M. (2014). University partnerships for co-designing and co-producing urban sustainability. *Global Environmental Change*, *28*, 153-165.

Tukker, A. (2015). Product services for a resource-efficient and circular economy–a review. *Journal of Cleaner Production*, *97*, 76-91.

von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, 27(2), 229-257.

Whitmer, A., Ogden, L., Lawton, J., Sturner, P., Groffman, P. M., Schneider, L., ... & Bettez, N. (2010). The engaged university: providing a platform for research that transforms society. *Frontiers in Ecology and the Environment*, *8*(6), 314-321.

Yuan, Z., Bi, J., & Moriguichi, Y. (2006). The circular economy: A new development strategy in China. *Journal of Industrial Ecology*, *10*(1-2), 4-8.

4

THE WASTE-RESOURCE PARADOX: PRACTICAL DILEMMAS AND SOCIETAL IMPLICATIONS IN THE TRANSITION TO A CIRCULAR ECONOMY

The European Union has vowed to transition from a linear to a circular economy (CE). Many innovations, new business models, and policies have begun to emerge to support the push for further institutionalizing CE practices. A large portion of these attempts are based on transforming a flow currently labeled as a waste stream into a value proposition, i.e., a resource. However, this ironically increases the risk of creating a demand for these waste streams, which thereby may become commodified. In this article, we unpack the inherent dilemmas and implications created by this phenomenon, which we define as the Waste-Resource Paradox (WRP). Understanding the WRP is highly relevant, as its manifestation may lead to situations in which the further establishment of "circular" practices may reinforce linear economy by sustaining a waste (over)production in the system or causing undesired social or environmental repercussions. This can tighten a lock-in of the existing linear structures counteractive to CE that have not been explicitly identified or explored to date. We observed that the WRP may evolve and morph throughout time, across boundaries or respective to different societal sectors. Based on our findings, we highlight the profound implications of the WRP for the future of circularity and the potential consequences for a transition to CE.

Keywords: Waste and resource management, circular economy, transitions, closing loops, waste-resource paradox, lock-in

This article is reproduced here as published in its original source:
Greer, R., von Wirth, T., & Loorbach, D. (2021). The Waste-Resource Paradox: Practical dilemmas and societal implications in the transition to a circular economy. *Journal of Cleaner Production, 303*, 126831.

4.1. INTRODUCTION: CIRCULAR ECONOMY IN EUROPE

As a society, we are producing increasing amounts of waste, exceeding the earth's capacity for regeneration and natural resilience (Steffen et al., 2015). In 2018, the total waste generated in the 27 European Union (EU) member states by all economic activities and households amounted to over 23 million tons (Eurostat, 2020). Furthermore, the global annual waste generation is projected to increase by 70% by 2050 (World Bank, 2018). It is therefore widely posited that we are in desperate need of a substantial reduction of these wastes. One way to conceptualize such a seminal waste reduction is by envisioning a transition from a linear to a circular economy. The circular economy (CE) has become a central concept used in academia, policy, and industry, defined by its aim to gradually decouple economic activity from the extraction and consumption of finite resources and to design waste out of the systems (Korhonen et al., 2018; Kirchherr et al. 2017; Ellen McArthur Foundation, 2020).

Within the EU context, the European Green Deal launched a strategy to scale up the CE from a pioneering niche to the mainstream economic players, with the aim of making a significant contribution to achieving climate neutrality by 2050 and decoupling economic growth from resource use (European Commission 2019, p. 2). To fulfill this ambition, the EU needs to accelerate the transition towards a regenerative growth model that gives back to the planet more than it takes, advances towards keeping its resource consumption within planetary boundaries, and reduces its consumption respectively in the coming decade. Accordingly, this transition to a sustainable economic system has been included as an indispensable part of the new EU industrial strategy (European Commission, 2020). With such a time-pressing policy goals at hand, the urgency to take action is clear.

However, despite continuous research efforts for decades and several defined policy targets, the circular economy remains a contested and often fuzzy idea, which lacks further operationalization. The existing linear economic model persists as the dominant way of organizing economic activities. In response, many innovators have focused their efforts on circular innovations, in an attempt to slow the mass production of waste per year – basing their business model on the use of a waste from another (production) process as an input to their own, thereby "closing a loop".

These innovators may have good intentions and offer promising solutions for some materials; however, some efforts may lead to stabilization or increases in waste amounts, when considering the further commodification of these. The latter can be described as a *rebound effect*: when the environmental benefits created by an innovation are

mitigated or outweighed by secondary effects. That is, efficiency gains – e.g., in terms of reduced environmental impact – are lost because of an increase in demand for and use of the respective product or material (Zink & Geyer 2017; Gillingham et al., 2016; Berkhout et al., 2000). Furthermore, rising prices for waste may then also threaten the economic feasibility of certain innovation models or demand for adjustments in business models predicated on free or cheap waste as an input.

In research on sustainability transitions (Koehler et al., 2019; Loorbach et al., 2017), this is referred to as path-dependency and lock-in: the inclination of societal actors embedded within societal regimes towards making the existing material and waste generate "less bad" (i.e., optimizing). Governments designing circularity-oriented policies, as a typical regime actor in this context, use innovation policy and market instruments to incentivize businesses, industries, and consumers to increase efficiency and reduce waste and emissions, while supporting economic growth. Despite governments and policy embracing the transition to circular economy – like the Dutch government's ambition to have a full transition to a circular economy by 2050 ambition (Ministry of General Affairs, 2020), it is not straightforward that we will see a transition towards radically lower levels of resource extraction, consumption, waste, and emissions. A more likely result might be a shift towards improved recycling, loop closing, and a suboptimal transition in the waste industry from landfill and incineration towards material reuse and downcycling (PBL Netherlands Environmental Assessment Agency, 2020), instead of to a circular economy. Still, such incremental changes in end of life waste treatments run the risk of clearly missing the ambitious decoupling targets.

Given the ecological degradation (IPBES, 2019), resource geopolitics (Global Harvest Initiative, 2016), and mounting societal pressures, it is also likely that it will be increasingly difficult and costly to achieve further improvements. Still, alternative technologies, new business models and (niche) lifestyles are emerging that can become steppingstones towards future economic models based on "sustainable" circularity, with the lowest possible environmental footprint and the highest possible ecological, social, and economic value creation. On the longer term, such a transition will include deep institutional (economic, legal, behavioral) and infrastructural changes.

In a transition, it is highly uncertain how a system shift takes place, but it inevitably emerges out of friction between new elements and incumbent elements: resulting in destabilization of the current regime (Loorbach et al., 2017). During such a transition process, there is a period in which elements of the existing system remain, but previously experimental innovations begin to further institutionalize. The incumbent structure – the regime – begins to become challenged by alternative methods and

models – niches – which may weaken the regime's initial airtightness (Schot & Geels, 2007). This destabilization of the current regime and emergence of niche alternatives results in a "transition zone" of change dynamics (Loorbach et al., 2020). In the transition zone from a linear to a circular economy context, the clash and frictions between the niche and regime elements bring about the phenomenon we analyze here: the Waste-Resource Paradox (WRP). Unpacking the dynamics and implications of the WRP creates awareness about risks and tradeoffs in the steps taken towards an intended transition to a circular economy.

4.2. CONCEPTUALIZING THE CIRCULAR ECONOMY AND THE WRP

To come to a common understanding on what it means to be "circular," it is of value to revisit what is the essence of a circular economy. As is indicated by a meta-analysis of circular economy definitions (Kirchherr et al., 2017), the foundation of CE is built on:

1. The least possible extraction of virgin material from the earth,
2. Energy efficiency towards a low-carbon economy,
3. Economic prosperity, and
4. Social equity for current and future generations.

Thus, "circular innovations" that base a business model on the consumption of waste are not fully contributing to a circular economy *unless they contribute to the lessening of the virgin material extraction from the earth.* If the same amount of production continues, the innovation that closes a loop does not actually make the system become less extractive – there is just more "stuff" held up in the system stock. This is why a systems approach must be taken to appreciate the full picture and to analyze the WRP within the CE through a transition perspective.

In its broadest sense, the WRP is the paradox that a certain material at any time could be considered a waste or a resource: depending on the perspective of the handlers, the practicality of its use at the end of life, the cultural and geographical context surrounding it, and the legal backdrop on which is it evaluated. The material output at the end of a production process or life cycle is not inherently either a waste or a resource, and it is not determined fully by the material label, physical value, or utilization potential. Its label and perceived monetary value often depend entirely on who is setting the rules of the market game and what the dominant party (e.g., the government, a company manager, a contract broker) defines the standards and prices of materials to be. This complexity and the related system dynamics are illustrated in Figure 5:

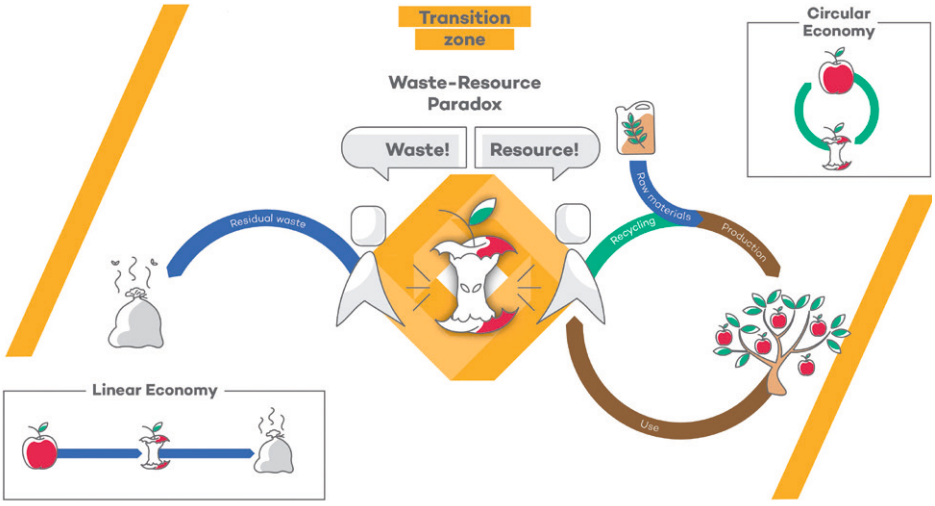


Figure 5: Emergence of the Waste-Resource Paradox in the "transition zone"

While there has been much attention and research devoted to the acceleration of circular economy, there were no studies our team could find that addressed the particular phenomenon of when a circular innovation might actually reinforce a linear economy. Some literature has touched to some extent on similar matters; for example, Camacho-Otero et al. (2018)'s literature review showed that most existing scientific work on circular models and consumption focused on identifying factors that drive or hinder the consumption of circular solutions, and shares the skepticism of our paper concerning what constitutes a circular business model. Ghisellini et al. (2016) argue that the EU's main policy focus is on promoting efficient and effective waste management, aiming at improving recycling rates in Europe, supporting one of the assumptions this paper is based upon. However, no studies were found that criticize or offer insights into what policies may mistakenly be considered circular while long-term impact could have undesired consequences. Zink and Geyer (2017) assert that sustaining the loops of production and consumption in the economy by keeping materials in the economy for as long as possible may create issues: there is a cap on material circulation, and the possibility of rebound effects is a real threat. Lastly, Andersen (2007) states that the extra cost of improving and refining a circular material flow will inevitably reach a point where the cost exceeds the corresponding benefits to society. While all of these studies relate to our observed phenomenon of the Waste-Resource Paradox, it has not been fully conceptualized to date.

In this paper, we further unpack the notion of the WRP to illustrate the large-scale importance and consequences for transitioning to a circular economy. To prevent

an unintentional and undesired reversion to an enhanced lock-in of linear economy (under the guise of circularity), it is important to expose unintended implications of closing loops and of the subjective labeling of a material as a waste or resource without premeditated consideration of the resulting ramifications. The WRP raises this question of whether circular innovations are truly contributing to progress towards a CE, and what further implications this has on a national or global scale for a just transition. Through our conceptual lens of the WRP, we examined materials and whether they were defined as resources or as waste. We observed that this had material, energy, economic, and social implications. These are the four dimensions around which we frame this research following these guiding research questions:

What are the systemic dynamics at play and the societal implications of the Waste-Resource Paradox, and how can the WRP help explore dilemmas for (circular) business and policy?

4.3. METHODOLOGICAL APPROACH

To test and explore the implications of the WRP, we took an iterative approach. This study was based on a literature review, observed practices, interviews with stakeholders dealing with circularity, and exemplifying case studies. First, we conducted desk research, including a literature review on the circular economy – focusing on business, policy, and innovation – and a policy analysis, with the geopolitical scope of the European Union and the Netherlands in particular.

We participated in a total of 21 meetings over the course of 15 months between July 2018 and September 2019 with circular hubs within the Netherlands to observe individual businesses and business-policy interactions and dialogues. Our empirical work following led us to observe potentially counter-transformative innovations operating under the label of circularity.

As we began to notice a pattern of transformations of wastes becoming used as resources, we conceptualized the paradox. For another related paper by the same authors (Greer et al. 2020), we conducted semi-structured in-person interviews (11) with members from a corporation, the Dutch government, and entrepreneurs working on circularity – from which we had also started to formulate the framework of this paradox. We reviewed these interviews to extract examples for the current paper.

After the theoretical prototyping for the WRP framework, we validated the conceptual innovation through another round of desk research and additional dialogues and investigation. This included a document analysis, involving grey literature and policy

documents like project reports, governmental reports, and a third-party material exchange platform. We conducted two workshops to validate the concept, discussing and reflecting upon the WRP with experts (in waste and resource management, circular economy) (7), businesspeople (4), and representatives of national ministries (3). The WRP was additionally reflected in expert meetings with cross-societal stakeholders, such as CE experts, advisors, and researchers as well as in the context of a Food-Energy-Water nexus expert meeting with 37 researchers, practitioners, and policymakers, which took place in The Hague, Netherlands in October 2019.

After this further exploration, we conceptualized the four dimensions in which the WRP plays out: realizing the material, energy, economic, and social implications brought about by their respective dilemmas. The analysis of these dilemmas was informed by the three pillars of sustainability – environmental, economic, and social – to each of which a circular alternative should substantially contribute. For the purposes of this analysis, we also considered the "material" and "energy" aspects that make up the environmental pillar as separate entities, to be able to illustrate the tradeoffs and dilemmas encountered even within the same pillar, across these category lines. We then used the conceptual framing to look at specific cases in existing literature and empirical cases in an exploratory way to illustrate the different WRP dilemmas and implications empirically. Lastly, we analyzed the geopolitical, legal, and governance entanglements involved in, affecting, and affected by the WRP.

4.4. WRP: SYSTEM DYNAMICS AND SOCIETAL IMPLICATIONS

4.4.1. Key dimensions of the WRP to a CE

Transforming a waste into a resource has potential to contribute to the advancement of the circular economy, as is generally intended. However, the problem occurs when decision-makers, policy makers, investors, entrepreneurs, or consumers assume that the latter positive contribution is automatically true – when a material traditionally going to waste instead becomes an input to another product or process, thereby closing a loop. As desirable as that may appear, it must first be carefully considered how the transition of a waste to resource – i.e., WRP – affects CE in the long term and at what level of impact. It is crucial understand the major impact the WRP can have on society, businesses, and the transition to a circular economy. In order to validate our conceptual claims about the WRP and to further understand the inherent dilemmas and implications, we identified salient empirical illustrations, which we describe in the following section.

We highlight the dilemmas of the WRP along the three pillars of sustainability: environmental, economic, and social. Further, we have divided the environmental pillar's dilemmas and implications into "material" and "energy," because they are both very important – but also distinct – aspects of the WRP. We use these as our four guiding analytical dimensions, as shown in Figure 6:

Figure 6: Guiding analytical dimensions of the WRP, as related to the transition to a CE

The perspective of the WRP helps to better differentiate the dilemmas and implications of the chosen examples.

4.4.2. Practical dilemmas of WRP dynamics

The WRP in practice leads to a variety of challenges for businesses. In this section, we discuss business models that create a new demand for an existing or temporary waste in a variety of sectors, and we examine the dilemmas they pose. Table 5 provides an overview of our selected illustrations.

Table 5: Dilemmas of the WRP explored in practice

Dimension of CE	Example	Sector	Dilemmas in practice, as related to WRP
Material	QMilk	Fashion / Agriculture	Closing a material loop, which incentivizes overproduction
	Too Good to Go	Food	Cascading and value retention, which removes the financial disincentive of overordering (and thereby, overproduction of the goods ordered)
Energy	Precious Plastic	Plastics	Reducing plastic waste, which requires a new high energy demand to be processed
	Sodexo	Food / Chemical Industries	Reducing food waste, which requires extra transport and fuel (in the EU legal context)
Economic	GroenCollect	Food / Energy	Creating new use for an old waste, which may result in a potential commodification of waste and a new market barrier for circular SMEs
Social	Agbogbloshie	Electronics	Secondary material recovery, at a cost to human health

The context surrounding WRP cases and their corresponding dilemmas in Table 5 is expounded upon in the following text.

4.4.2.1. Material dilemmas

A first case we identified was "QMilk," a German-based company designing textile products from the otherwise wasted milk in 2011 during a year of unintended national dairy overproduction. This surplus would have been thrown out (in principle) and have gone to waste – until the QMilk founder realized the casein (a protein present in milk) made a suitable structure to weave a silky fabric and launched her company based on this new product (Di Ciancia, 2017). Though this innovation seems to fill the criteria of a circular business model at first, it is important to examine more closely its implications for CE and dairy farms over the course of multiple years. Closing a loop, in this case (as well as others beyond), would actually incentivize overproduction – the opposite direction of CE.

"Too Good to Go" is an example of a Danish entrepreneur's approach to saving food waste. The concept behind the business is to procure remaining food from supermarkets, cafes, and restaurants at the end of the day, to collect and resell to consumers at a lower price than the original seller (Too Good to Go, 2020). This is an example of cascading (Campbell-Johnston et al., 2020), which – as a general concept – contributes to a circular economy. However, this too hardly incentivizes businesses to make the most accurate possible estimations of daily food sales. Knowing that they

could still make profit on surplus food ordered, the financial disincentive of waste management costs for disposing of excess inventory is thereby removed. Cascading can slow loops, but a more efficient scenario would be to have avoided unnecessary food production in the first place.

4.4.2.2. Energy dilemmas

We also explored cases in which the attempt to lessen material waste results in increased energy use. This led us to the example of "Precious Plastic," a platform for plastics recycling and 3D printing. Like many other similar companies, they convert the waste into plastic pellets, which are then used as filaments for 3D printers – causing a new demand for higher energy consumption. Furthermore, plastic is very difficult to recycle properly (Balogun & Oladapo, 2016), because of the complexity and variety of plastics recycling – each type requiring a unique sorting bin, heating temperature, and recycling process. Most consumers do not know how, do not have the time, or do not care to sort each unique type of plastic as needed; this results in a very low-value medley of recycled plastics, unsuitable for most potential applications.

Another such example was uncovered in an earlier work of these authors (Greer et al., 2020): a study addressing the drivers and barriers in the progression towards a transition to a circular economy. One of the top wastes of the multi-national catering company called "Sodexo" was orange peels, for which their innovation team found a circular solution. They paired up with "Spaak," a company that uses supercritical CO_2 gasification to extract limonene, 10-fold citrus oil and pectin from orange peels, paying Sodexo for their "waste" and effectively turning it into a resource – a manifestation of the WRP. The oranges for catering services are transported to Sodexo by truck. Because their peels are legally considered a waste, EU sanitation and health regulation laws mandate that they cannot be transported in the same vessel as foodstuff, i.e., this truck must drive away empty. Then, *another empty truck* must drive to Sodexo to pick up and transport the peels to the next site. This saves material from going to waste, but this discrepancy in consideration as a waste (law) vs. resource (companies) requires twice the amount of fuel and energy to make use of the good.

4.4.2.3. Economic dilemma

Further, we observed business models that have a waste stream as a critical input and build their business case based on the free access to this waste. "GroenCollect" is a small social foundation, with branches in several major cities in the Netherlands, that collects food residues from households and businesses at a discounted price (compared to what traditional waste management companies charge). For example, companies and citizens can place the old, no longer edible bread in the "bread bins," which is

collected and repurposed as fuel to create biogas. Other materials are preserved in their highest-value state, such as old coffee grounds which can be used to grow oyster mushrooms (GroenCollect, 2020). The business model of GroenCollect could be put in jeopardy if the stale bread they collect as the backbone of their business suddenly becomes a priced commodity. In the context of a waste potentially being utilized in such a magnitude that a demand for it is created and a price is therefore assigned to it, waste-producing companies could actually profit their waste production, while SMEs and alternative startups with small profit margins (before the price assignment to the waste) could be put out of business when their input costs rise (too high), based on this new increase of cost to access waste. The same logic could be applied to and put in danger other innovative SMEs supporting the CE; a new barrier to the market would be created as a result of such waste commodification.

4.4.2.4. Social dilemma

Within the electronics industry, we identified a particular social dilemma directly tied to the WRP. When there is a discrepancy between the countries disposing of electronics and the countries in which they are disposed of the perception of value of a material output, it can lead to exposure to toxicity from manually dismantling waste electrical and electronic equipment (WEEE) at informal recycling plants (i.e., E-waste dumps), like in the case of "Agbogbloshie" recycling centers in Accra, Ghana. Agbogbloshie has achieved notoriety as one of the most polluted slums in the world by hosting the arguably largest informal electronic waste dump in the world. In this area of Ghana, the urban poor of Accra have been spending years recovering parts and metals extracted from electronics scrapped by Europe and USA (Grant & Oteng-Ababio, 2012). Just like at Agbogbloshie, other areas of Ghana, Kenya, Nigeria, and Liberia have been importing used EEE from the EU, where informal recyclers engage in work such as openly incinerating cables and plastic parts to liberate copper and other metals (Nordbrand, 2009; Secretariat of the Basel Convention, 2011). Although urban mining may reduce the extraction of virgin rare earth and critical metals, toxic residues from manually breaking down WEEE are left behind. These residues include localized concentrations of toxic waste, damaged ecosystems, and harm done to the bodies of the workers who perform much of the processing and sorting (Sullivan, 2014), highlighting the social injustices of current practices surrounding this example of the WRP.

4.5. IMPLICATIONS OF THE WRP DYNAMICS AND DILEMMAS FOR CE

4.5.1. Material implications

During the initial year of operation, "QMilk" indeed offered a viable, sustainable way to close a loop. However, this new business model was built entirely dependent upon

heavy milk production; thus, for every year after the original outlier that sparked the business idea, it might have the reverse intended effect: having turned a waste into a commodified resource. Setting aside all of the negative effects associated with dairy farming – an industry whose sustained existence itself already creates substantial environmental threats (Mu et al., 2017; Gerber et al., 2013; Place & Mitloehner, 2010) – the overproduction (a practice to be avoided in general across all industries) became rewarded. Instead of disincentivizing overproduction through waste processing fees or other regulatory measures, the reverse occurred – a steady, constant demand for unnecessary waste. This indicates that the "circular" model could likely create a rebound effect: causing more material (in this case, milk) to be wasted in the long-term, overcompensating for the marginal efficiency gains on which the business was based.

In the case of "Too Good to Go", we identified the risk of removing the financial disincentive of food overproduction. If restaurant managers, for example, calculate that they will be paid for all the food they produce per day, this is hardly an incentive for accurate estimation of *per diem* food sales. If the overproduction of food was sure to be a net loss at the end of the day because of its associated production and disposal costs, there is a much greater chance that the procurement quantities will be more accurate estimations. With the integration of Too Good to Go into their supply chain, daily overproduction of food becomes a financial non-issue. Understanding the WRP encourages us to think critically, also particularly about the number of meals Too Good to Go advertises on their website that have been "saved." The advertised numerical value accounts for how many meals were bought and resold. However, this does not equate to saving wasted food, if that food might not have been produced in the first place (without the presence of a reseller).

4.5.2. Energy implications

Within the circular economy, the focus is by and large on material – rather than energy – streams. This puts policy and businesses striving towards circularity at risk for burden shifting: wherein the overall environmental impact is not necessarily lessened by reducing waste production, but rather shifted to a different life cycle stage or type of waste (Algunaibet & Guillén-Gosálbez, 2019; Jackson & Brander, 2019). 3D printing is extremely energy intensive (Christensen et al., 2019), and life cycle analyses of plastics therefore indicate that incineration at their end of life can often be more environmentally efficient than recycling (Khoo, 2019; Pivnenko et al., 2015). Furthermore, plastics deposited in recycling bins are often destined for oversea plants for final reprocessing, requiring much transportation fuel and energy (Mohammed et al., 2018). This illustrates a trade-off emerging from the WRP: exchanging material consumption for energy consumption.

In particular industries, we found that the legal definition of waste or the cumbersomeness of another structural procedure impeded the ability and feasibility of using a waste as a resource. As an example, in the food industry: as soon as a food-related byproduct leaves the walls of the building in which it was created, it is legally labeled a waste in the Netherlands (Ministry of Agriculture, Nature, and Food Quality, 2018). This can cause issues of accessibility for those innovators wanted to explore a way to close that loop, or – in the case of Sodexo – could create logistical complications which result in an increase of energy demand and carbon emissions.

4.5.3. Economic implications

GroenCollect's business model is based on the ability to take food waste for free and creating a product from which they can make profit. However, if larger businesses creating waste start to realize that they are actually offering a resource (because it is the input to something profitable) – not a waste – they may start charging for the material. This manifestation of the WRP would thereby commodify the waste, which would constitute a threat to both CE in general and particularly to this example of one business model with a positive environmental impact. In this sense, the WRP could also create a new market barrier, especially for new startups and SMEs. The WRP's economic implications especially affect these startups and SMEs, whose business models have a small profit margin and are based on the free or paid collection of waste.

4.5.4. Social implications

The discrepancy between nations about what is a waste and what is a resource can result in major social implications for cases where the WRP occurs internationally. As an illustrative example, in most countries of the Global North, a broken electronic device (e.g., laptop, tablet, mobile phone) is considered a waste. This "waste" is then collected and dumped, most likely in a country of the Global South, where it is not perceived as a broken laptop, but as a field of valuable metals. Under the current crude recycling methods, insufficient precautionary measures and protocol (if any) are taken towards worker protection (Leung et al., 2008). The endangerment of informal workers at waste dumps like in Agbogbloshie by handling WEEE is a direct social implication emerging from the Waste-Resource Paradox spanning country borders and cultural norms. Because volumes of e-waste and e-scrap are projected to increase (Minter, 2013), it is with urgency that the social implications of the WRP counterproductive to a just CE are carefully considered and fully understood.

4.6. SYNTHESIS AND REFLECTIONS

In this paper, we bring attention to a phenomenon that we call the Waste-Resource Paradox (WRP). Despite its widespread occurrence, until now it has gone highly unnoticed and understudied – not yet fully conceptualized to date. Through our illustration and analysis of the WRP, we argue that awareness of this phenomenon is crucial during our societal endeavor to transition from a linear to a circular economy, to understand the potential long-term and systemic implications of turning a waste into a resource. Furthermore, we implore policymakers, investors, entrepreneurs, and other decisionmakers to consider the WRP in their decision-making processes and evaluations for a more comprehensive understanding of if we are indeed supporting innovation that advances us towards our stated goal of a circular economy – i.e., material extraction and consumption reduction, highest value preservation, and social justice. We illustrated its manifestation in the context of selected cases from a European perspective with a global system view, to catalyze discussion about the WRP's potential ramifications.

4.6.1. Considerations, based on the WRP

4.6.1.1. Linear economy lock-in and rebound effect

As entrepreneurship around circularity becomes saturated, it is possible that these business models based on using waste will create a demand, such that current regime incumbents are not incentivized to reduce or minimize their waste production by waste management costs. There is a future scenario possible wherein the demand of specific wastes streams becomes so entrenched in our industries and society that we unintentionally and contradictorily create a linear economy lock-in through an attempt to transition to a CE through optimization of the current linear system – rather than accelerating the necessary radical innovation fitting a new economy regime (CE). While Zink and Dreyer (2017) have identified the cap on material circulation and the threat of rebound effects, the WRP perspective provides an understanding of the fuller picture. When the WRP is identified as occurring, it may serve as a warning signal for approaching a potential rebound scenario. In this way, it allows space to take preventative measures to curb or stop this effect from occurring before it becomes embedded in society.

4.6.1.2. Tradeoffs with energy use and treating the symptom

The cases illustrated in this paper highlight the necessity to be cautious when ignoring trade-offs at the waste-energy nexus. The reduction of material consumption still runs the risk of resulting in increases in energy consumption. We must consider the whole system and entire life cycle of a product to ensure that a seemingly circular

innovation is not simply shifting the environmental burden from the end-of-life phase to the manufacturing phase. As with the case of plastics recycling, it can be argued that recycling is only a compensation measure that involves objective and substantial material and energy loss in its process (Amini et al., 2007) – when a much more impactful innovation would address the source of the problem (i.e., ubiquitous plastic manufacturing and consumption).

4.6.1.3. New market barrier for SMEs

Another tradeoff to consider is the new market barrier for startups and SMEs that the likely commodification of waste over time brought about by the WRP would create. As a price is assigned to a material currently allocated as a waste, this may cause trouble in a business model with small profit margins. It means that larger companies in the regime will outlast and/or jeopardize smaller organizations attempting to break the market barrier: a natural exclusion mechanism that increases the stability of the existing regime.

4.6.1.4. Human health risks

A circular economy is not actualized unless it is just. The treatment of WEEE illustrates how the WRP across country contexts can result in the institutionalization of human health risks and systematized regular exposure to high toxicity. If we are to urban mine for critical and rare earth metals as a way to reduce and slow virgin material extraction, we must create worker protection laws and safety regulations to ensure that this is executed in such a way that large populations are not put in harm's way to do so. Here, it becomes clear that the WRP is not bound to geographical or administrative boundaries. Instead, it may require a transnational view to capture the emerging implications and in order to account for negative (social) impacts.

4.6.1.5. Law as impediment to circularity

In the transition zone between a linear and circular economy, it is possible that multiple actors or forces involved in practice have opposing labels simultaneously. The legal system and regulatory systems provide boundary conditions for different forms of the WRP to emerge, while may also offer the instruments or policy mixes (yet to be designed) in order to address some of the ramifications and unwanted implications of the WRP. In the aforementioned example of orange peels as the material in question, two companies succeeded in creating a use for unavoidable orange peels in a circular way together. Yet, despite both of the active parties in the material exchange recognizing it as a resource, hygiene laws dictated that it be named and treated as a waste. Because of this, twice as many trucks were needed to move the material. While considerations for hygiene are undeniably important, this is an example of regulations creating a need

for more fuel and transportation energy. It illustrates the need for critical thinking on how to uphold quality and safety standards while improving environmental efficiency. Furthermore, it raises the discussion of if and in which form novel regulations and standards emerge during the transitionary period bridging us from the linear economy towards a circular economy.

4.6.2. Caveats and limitations

The select evidence presented is not intended to convey the message that transforming a waste into a resource is counter-productive to circular economy. In fact, some actors and select industries appear to have devised a system for effectively reducing, and sometimes even eliminating, a certain material waste flow in a manner consistent with the core logic of CE. The risk lies when companies, organizations, governments, or investors assume that using a waste as a resource by finding a way to close a loop, by default, contributes to a CE. What this paper aimed to expose is that business models considered to be at least partially circular in everyday practice (and often presented, supported, and even funded as such) potentially may be working against a more fundamental transition.

The examples in this paper are intended to be illustrative of an important occurrence that needs to be addressed. The paper is not intended to deprecate any of the organizations described. We use them as an explicative instrument to drive more analytical thinking about the multi-sector societal implications of the WRP. Based on these, we hope to inspire discussion and criticism on what can truly qualify as "circular" and what consequences may result if the long-term ramifications in each of these societal sectors are not considered from the WRP perspective.

Similarly, it is important to note that the WRP should neither be conceived as solely good nor bad, but it calls for awareness around risks and uncertainties for new business models and a risk assessment of potential implications system wide. It is crucial to deal with the Waste-Resource Paradox, and understand its potential impact on society, policy, and waste (i.e., resource) management – which we must thoroughly and critically examine before accepting, welcoming, and investing in a circular innovation.

4.6.3. Implications for further research

The WRP is an inter-disciplinary phenomenon that requires multi-disciplinary research to be further studied. In this section, we recommend topics and questions for future research to address, which can further extend the findings of this paper.

While we have presented illustrative examples of how the WRP manifests in different sectors and material contexts, it appears relevant to substantiate our arguments with rigorous quantitative assessments of the WRP dilemmas. These WRP dilemmas have major implications for environmental impact assessment tools and modelling. For example: one of the most established and well-developed tools is a Life Cycle Assessment (LCA), used to evaluate the environmental impacts of a product or a service throughout its life cycle (during raw material acquisition, production process, use, and disposal of the product) (Ness et al., 2007). An LCA, by nature, looks at one product or process, but circular economy must be studied through a system lens. This incongruence in scopes can bring about misleading results, for example when an LCA would indicate an improvement in environmental efficiency of a product, which may have a net negative impact when considering other stocks and flows within the entire system. The WRP brings to light some of the complications of "allocations" in LCA, i.e., the explicit labeling of an outflow to be a bi-product (an output of value) or a waste (unintended stream released into the system with no positive economic value or contribution to another product). It also illustrates the shortcomings and inconsistencies in "demarcations" between what is included in the product system and what is excluded. A consequential LCA (Rebitzer et al., 2004) may offer an incrementally more holistic evaluation: evaluating the impact of a new policy or implementation with a micro-economic approach in background combined with an LCA approach in foreground. However, this tool is much more time- and resource-intensive, while still not offering a fully comprehensive understanding.

In our early stages of this research, we attempted an explicatory study analyzing historical price assignment to secondary materials over time and contextual variables, events, and influencing factors surrounding the monetary switch from waste to resource. However, after a thorough search, no such records or databases on which we could base this analysis could be found to exist. We recommend that future research applies *post hoc* analyses of historical cases of the WRP, which could offer predictive insight and/or warning signals of a WRP manifestation likely to occur. Building on our research in this way could also offer deeper insight into group and individual decision making to understand: how was a price assigned to or negotiated for a formerly non-commodified waste? Furthermore, there are no existing decision-support tools for actors in practice to help navigate the dilemmas highlighted by the WRP. For those striving to support circular innovation in an intelligent and meaningful way, modelling such systemic perspectives will be too complex; there appears to be a need in policy and practice for simplified "maps" (i.e., heuristic decision schemes) that provide orientation.

4.6.4. Recommendations for policymakers, investors, and entrepreneurs

By exposing the WRP, we hope to shed light on how to align short-term solutions with long-term visions. In some cases, it may actually be desirable that some "circular" innovations fail, considering if they will continue supporting the circular economy in the long run – or if they rather might have the reverse effect. This calls for policy and governance that helps navigating the WRP appropriately with the most sustainable outcomes possible, i.e., stronger legal and financial incentives for innovations acknowledging potential rebound effects and WRP dynamics.

4.6.4.1. Contract considerations

One potential solution for policymakers and investors to help lessen the problematic aspects of supporting circular innovation, elucidated by the WRP, is shorter contract or funding durations. For example, QMilk made good use of waste for the initial year of its solution for the dairy industry. However, funding and support should be limited to the time it takes to "right the wrong." Funders, policymakers, and other decision-makers involved in such a contract should assess and re-evaluate it regularly, ensuring not to create a demand for continued, intentional overproduction.

The need for shorter contract durations can also be observed empirically in a case of municipal waste management. Within the Netherlands, many municipalities entered into long-term contracts with waste incinerators and waste separation companies that keep them locked in to the existing waste-based system (van Raak et al., 2014). Despite innovations for efficiency improvements made in waste sorting, reuse, and municipal recycling, cities remain locked in to producing a minimum amount of waste on a municipal level for decades – otherwise met with a fine (NOS News, 2014). Learning curves and more radical innovations are systematically ignored; shorter or more flexible contracts would allow for *adaptability*.

This assertion was supported in practice by an example from the Dutch Ministry of Infrastructure and Water Management. In an effort towards circularity in the furniture sector, contracts were re-formulated to teach the skill of *repairing* existing furniture instead of *building* new furniture. This helped mitigate the "winners and losers" in transitioning to a CE discussion; thousands of builder jobs were not lost – only adapted. Furthermore, contracts were made for five-year periods so that, in the context of evolving innovations, a mutually beneficial and progressive contract for the Dutch Ministry and CE could be regularly updated and re-negotiated (Greer et al., 2020) to allow space for novel efficiency improvements.

4.6.4.2. Reflexive governance

The discussion of the preceding section calls for the implementation and practice of reflexive governance: a type of collective approach to cope with societal challenges – which must be predicated on a diagnosis of ongoing patterns and their constraints, how to act in their context, and considering how to improve them (Voß, Bauknecht, & Kemp, 2006). It refers to shaping societal development in the light of the reflexivity of steering strategies - the phenomenon that thinking and acting with respect to an object of steering also affects the subject and its ability to steer (Voß & Kemp, 2015). The Waste-Resource Paradox demonstrates that governments, policy makers, and business managers (among others) should not blindly support innovation that appears to close a loop; these decision makers should regularly reflect on the short-term efficiency gains aligning with the long-term vision of circularity.

Along the same vein, funding support should be proportional to the long-term contribution to a circular economy. This can imply tiered funding or selected funding, in terms of the duration and/or amount of funding allocated – as directly related to their long-term impact. Evaluating policy, innovations, and investment opportunities through the WRP lens can expose and refocus companies relying on waste that ideally should not exist in the first place. Some may contribute now as a short-term fix, but we should aim to phase (the need for) them out as quickly as possible. Therefore, funding, policy, and other support should differ per innovation – continuing only so long as it aligns with a long-term circular strategy.

4.6.4.3. Lessons for entrepreneurs

The implications for CE of the WRP discussed in this paper indicate that we must not only consider single flows or single countries when attempting to accelerate the transition to a circular economy; rather, we must be cognizant of the interdependencies and indirect effects of innovations in such a globalized context. This resonates with a principal element of transition theory: such an examination makes clear the prerequisite and importance of systems thinking to address societal challenges. Similar to our recommendations to policymakers and investors, we strongly urge emerging circular entrepreneurs to evaluate the consequences of their innovation across time and space with the WRP in mind. We encourage new (and current) business owners and innovators to orient their creative development towards *process innovation* over repurposing waste (Henry et al., 2020). We implore them to be strategic, explorative, and self-reflective about their values and the long-term impact of their business in different lifespan and growth scale scenarios, and furthermore, to consider externalized (material, energy, economic, and social) costs and repercussions.

4.7. CONCLUSIONS

The WRP describes the phenomenon that a certain material at any time could be considered a waste or a resource: depending on the perspective of the handlers, the practicality of its use at the end of life, the cultural and geographical context surrounding it, and the legal backdrop on which is it evaluated. It is further paradoxical because the innovations related to the WRP are generally designed to close loops, reduce waste, and advance the transition to a circular economy. However, they may result in being counter-productive to CE by catalyzing a rebound effect of material use, creating a tradeoff with energy demand, bankrupting circular startups and SMEs, and posing a risk to human health. Unpacking the dynamics, dilemmas, and implications of the WRP creates awareness about risks and tradeoffs of building novel business models upon waste as a commodity and the implications this has in the transformation to a circular economy. Furthermore, it allows policymakers, investors, and business owners to think through the long-term implications of innovations with circular intents, and what these could mean for the progression towards a sustainable, just circular economy. It offers a widened decision-making capacity in their role during the transition zone on the path from a linear towards a circular economy.

4.8. REFERENCES

Algunaibet, I. M., & Guillén-Gosálbez, G. (2019). Life cycle burden-shifting in energy systems designed to minimize greenhouse gas emissions: Novel analytical method and application to the United States. *Journal of Cleaner Production*, *229*, 886-901.

Amini, S. H., Remmerswaal, J. A. M., Castro, M. B., & Reuter, M. A. (2007). Quantifying the quality loss and resource efficiency of recycling by means of exergy analysis. *Journal of Cleaner Production*, *15*(10), 907-913.

Balogun, V. A., & Oladapo, B. I. (2016). Electrical energy demand modeling of 3D printing technology for sustainable manufacture. *International Journal of Engineering,* 29(7), 1-8.

Berkhout, P. H., Muskens, J. C., & Velthuijsen, J. W. (2000). Defining the rebound effect. *Energy policy*, *28*(6-7), 425-432.

Campbell-Johnston, K., Vermeulen, W. J., Reike, D., & Bullot, S. (2020). The circular economy and cascading: towards a framework. *Resources, Conservation & Recycling: X*, 100038.

Christensen, P.R., Scheuermann, A.M., Loeffler, K.E. et al. (2019). Closed-loop recycling of plastics enabled by dynamic covalent diketoenamine bonds. *Nat. Chem.* 11, 442–448. https://doi.org/10.1038/s41557-019-0249-2

Di Ciancia (2017, 9 December). *QMilk, a new generation in fabrics*. Conscious Welum. Retrieved November 23, 2020, from https://welum.com/article/qmilk-new-generation-fabrics/

EBB (2015). Delivering resource-efficient products. *How ecodesign can drive a circular economy in Europe*.

Ellen MacArthur Foundation (2020). *What is Circular Economy?* Retrieved July 10, 2020, from https://www.ellenmacarthurfoundation.org/circular-economy/concept

European Commission. (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. *The European Green Deal.*

European Commission (2020). *Circular Economy Action Plan: For a cleaner and more competitive Europe.*

Eurostat (2020). *Waste statistics*. Retrieved November 23, 2020, from https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Total_waste_generation

Gerber, P. J., Henderson, B., & Makkar, H. P. (2013). *Mitigation of greenhouse gas emissions in livestock production: a review of technical options for non-CO2 emissions* (No. 177). Food and Agriculture Organization of the United Nations (FAO).

Gillingham, K., Rapson, D., & Wagner, G. (2016). The rebound effect and energy efficiency policy. *Review of Environmental Economics and Policy*, *10*(1), 68-88.

Global Harvest Initiative (2018). *2018 Global Agricultural Productivity (GAP) Report*.

GroenCollect (2020). *GroenCollect*. Retrieved on November 23, 2020 from http://www.groencollect.nl/

Hartley, K., van Santen, R., & Kirchherr, J. (2020). Policies for transitioning towards a circular economy: Expectations from the European Union (EU). *Resources, Conservation and Recycling*, *155*, 104634.

Henry, M., Bauwens, T., Hekkert, M., & Kirchherr, J. (2020). A typology of circular start-ups: An Analysis of 128 circular business models. *Journal of Cleaner Production*, *245*, 118528.

Jackson, D. J., & Brander, M. (2019). The risk of burden shifting from embodied carbon calculation tools for the infrastructure sector. *Journal of cleaner production*, *223*, 739-746.

Kahler, M. (Ed.). (2011). *Networked politics: agency, power, and governance*. Cornell University Press.

Khoo, H. H. (2019). LCA of plastic waste recovery into recycled materials, energy and fuels in Singapore. *Resources, Conservation and Recycling*, *145*, 67-77.

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

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., ... & Fünfschilling, L. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*, 1-32.

Leung A. O. W., Duzgoren-Aydin N. S., Cheung K. C., et al. (2008). Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in southeast China. *Environmental Science & Technology,* 42(7): 2674-2680.

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability transitions research: transforming science and practice for societal change. *Annual Review of Environment and Resources*, *42*.

Ministry of Agriculture, Nature, and Food Quality (2018, June). *The first food safety statement.*

Ministry of General Affairs (2020). *Circulaire economie*. Retrieved November 23, 2020, from https://www.rijksoverheid.nl/onderwerpen/circulaire-economie

Mohammed, M. I., Wilson, D., Gomez-Kervin, E., Rosson, L., & Long, J. (2018, November). EcoPrinting: investigation of solar powered plastic recycling and additive manufacturing for enhanced waste management and sustainable manufacturing. In *2018 IEEE Conference on Technologies for Sustainability (SusTech)* (pp. 1-6). IEEE.

Mu, W., van Middelaar, C. E., Bloemhof, J. M., Engel, B., & de Boer, I. J. M. (2017). Benchmarking the environmental performance of specialized milk production systems: selection of a set of indicators. *Ecological Indicators*, *72*, 91-98.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., & Olsson, L. (2007). Categorising tools for sustainability assessment. *Ecological economics*, *60*(3), 498-508.

NOS News (2014, May 23). *Financial penalty for too much waste sorting*. Retrieved on December 3, 2020 from https://nos.nl/artikel/651848-boete-voor-te-veel-afval-scheiden.html

PBL Netherlands Environmental Assessment Agency (2020). *Circulaire economie rapportage 2020.*

Place, S. E., & Mitloehner, F. M. (2010). Invited review: Contemporary environmental issues: A review of the dairy industry's role in climate change and air quality and the potential of mitigation through improved production efficiency. *Journal of Dairy Science*, *93*(8), 3407-3416.

Pivnenko, K., Jakobsen, L. G., Eriksen, M. K., Damgaard, A., & Astrup, T. F. (2015). Challenges in plastics recycling. In *Sardinia 2015-15th International Waste Management and Landfill Symposium*. CISA Publisher.

IPBES (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany.

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., ... & Pennington, D. W. (2004). Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications. *Environment international*, *30*(5), 701-720.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Folke, C. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223).

Too Good to Go (2020). *Red eten help de planeet*. Retrieved on November 23, 2020, from https://toogoodtogo.nl/nl

van Raak, R., Loorbach, D. A., Verhagen, M., Verhoeven, P., Taanman, M., & Teernstra, M. (2014). Van Afval Af: Transitieagenda voor Gemeentelijk Afvalbeheer.

Voß, J. P., Bauknecht, D., & Kemp, R. (Eds.) (2006). *Reflexive governance for sustainable development*. Edward Elgar Publishing.

Voß, J. P., & Kemp, R. (2015). *Sustainability and reflexive governance: introduction*. Technische Universität Berlin.

World Bank (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.*

Zink, T., & Geyer, R. (2017). Circular economy rebound. *Jour\nal of Industrial Ecology*, *21*(3), 593-602.

5

THE CIRCULAR DECISION-MAKING TREE: AN OPERATIONAL FRAMEWORK

Because of the need to limit extraction of raw materials and reduce amounts and impacts of waste, countries and businesses are challenged to transition to a circular economy: an economic system in which the materials are reduced, reused, or recycled, but not wasted. Yet, transitioning from a linear to a circular economy implies societal-level, structural changes that have deep implications for existing business models and practices – and the current economic system is still largely organized around virgin material extraction and linear modes of production and consumption. Despite stated ambitions at various geographical scales to become more or fully circular, the outcomes still fall short of such visions. One important reason why the transition towards a circular economy is not proceeding as quickly as hoped can be found in the decision processes used by companies, investors, and policy makers. Suitable frameworks that support decision-making could thus be a key enabler of this transition, if based upon a circular and transformative, rather than a linear optimization logic. In this paper, we therefore explore a different decision-making logic that is developed based on circularity. This provides the basis for an operational framework designed to help decision-makers such as policymakers, investors, and entrepreneurs navigate trade-offs and take decisions considering the quality of innovation circularity and its respective diffusion potential. To develop, test, and refine our framework – the "Circular Decision-Making Tree" –, we synthesized insights from existing frameworks and conceptually integrated these with our understanding of transition theory and circular economy. We then verified the internal logics and applicability of the framework in a series of usability workshops across four application contexts (Netherlands, Brazil, United Kingdom, and South Africa) with feedback from a total of n=50 stakeholders from policy, practice, and academia. We critically discuss the application potential as well as the limitations and describe implications for future research to further validate the framework's logics and operationalization.

Keywords: Circular economy, decision-making, eco-efficiency, sustainable innovation, diffusion potential, sustainability transitions

This article has been accepted for publication with revisions in the academic peer-reviewed journal *Circular Economy and Sustainability*.

5.1. INTRODUCTION

5.1.1. Circular economy context

In response to ever-increasing waste production and interrelated socio-environmental challenges: governments, businesses, and scholars have begun to embrace and support the concept of a circular economy (CE) (Geissdoerfer et al., 2017). The CE is a radically different economic paradigm that prioritizes the reduction of raw material extraction through value retention and regenerative design (Blomsma & Brennan, 2017; Ellen MacArthur Foundation, 2021). The underlying purpose of adopting CE practices is to ultimately reduce virgin material consumption, eliminate waste, and decouple growth from material use (Ghisellini et al., 2016; Murray et al., 2017; Campbell-Johnston et al., 2020). Thus, not all movements within circularity contribute equally (or at all) to accelerating the desired transition to CE. Because a core value of CE is highest value preservation (Zink & Geyer, 2017), it is possible that a circular innovation may contribute to the acceleration of CE – but at a low magnitude, relative to an alternative innovation that scores higher in a hierarchy of CE value retention options. Furthermore, the Waste-Resource Paradox (WRP) occurring in the transition zone between a linear and a circular economy (Greer et al., 2021) elucidates that closing a loop through waste-based innovation (Henry et al., 2020) and turning a waste into a resource *may reinforce undesirable linear pathways* by incidentally creating a demand for said waste – thereby reinforcing its production, rather than deinstitutionalizing and breaking down its comfortable position in the supply chain (Greer et al., 2021).

Strategizing for and prioritizing higher-quality circularity proposals, solutions, and implementations may help to avoid low-value and low-impact CE solutions. Yet, even at the international EU level, "of the 36 CE Green Deals and 32 CE Best Practices, almost all aim at increasing recycling… Recycling, and low-grade recycling in particular, is still very much a linear solution. In addition to aiming for less resource consumption and waste generation, it is also important for a circular economy to focus on creating less environmental impact (including more value for ecology), and generating more added value for the economy" (PBL, 2017, p. 39). This indicates that, despite existing efforts in science and practice, the vision of a circular economy is not yet translating into broader action to transition.

5.1.2. Transition theory

One central challenge in transitioning to CE is aligning short-term actions with long-term visions. In this case, the field of sustainability transitions may serve as appropriate research for guiding the convening of actions and visions. Specifically, transition management uses sustainable development as a guiding principle and relates to

fundamentally new governance approaches (Loorbach, 2007). While attempts at transitioning from a linear to a circular economy are being made, fundamental change requires a clear vision of both the future goal and the inherent tradeoffs. In transition research, we speak about a regime, or paradigm shift: a fundamental and structural change in the incumbent cultures, structures, and practices (Rotmans & Loorbach, 2009). Regimes are described in transition literature as path-dependent by nature, meaning that current decisions within an incumbent context are made based on previous decisions in that context and are not independent. The path dependencies are "inevitable, because of sunk investments, benefits of scale, and the co-evolutionary dynamic within a regime. But such path dependencies over time ultimately imply the inability to change beyond optimization, hence causing systemic tensions and problems" (Loorbach et al., 2017, p. 605). However, these incremental improvements often embed the assumption of continuing the current regime (and therefore, may lead to fostering existing aspects of the current regime). Dominant forms of policy and management are currently mostly prioritizing optimization – incremental improvement in the current regime – thereby adding to the lock-in of the current systems (ibid). To transition to a circular economy, we argue that transformative – i.e., fundamentally different – innovations and policies must be supported.

When alternatives to the regime – niches, e.g., circular innovations or policies – are scaled, replicated, or embedded into other contexts, this is known as diffusion (Smith & Raven, 2012). Embedding refers to the adoption and integration of an innovation into existing institutions or regulations; translating addresses the process through which constitutive elements are replicated and reproduced elsewhere; scaling refers to the internal development and growth of niche innovations to a larger scale (von Wirth et al., 2019). Based on the concept of the WRP – which describes the paradox in the "transition zone" between a linear and circular economy, wherein a material can be considered a waste and a resource at the same time, warning about related dilemmas that may ensue from using waste as materials for production (Greer et al., 2021) –, we propose a new framework for decision-making in the transition to a CE. In this paper, we describe a new logic for operating decisions that may lead to more informed decisions towards circularity.

5.1.3. Complexity of circular decision-making

Despite stated ambitions at various geographical scales to become more or fully circular, the outcomes fall short of the visions (PACE, 2021; Towa et al., 2021; PBL, 2017; PBL, 2021). We hypothesize that this is rooted in a fundamental problem observable in current practices of decision-making: often, decisions are made based on linear decision-making principles. Many forces and pressures influence decisions made on the

CE – risk-aversion, stranded assets in linear business cases, path dependency of existing practices, locked-in institutions, and market fluctuations – which may prove difficult to penetrate or circumvent. However, another key challenge for amplifying the transition to CE is the still apparent lack of circular oriented governance and decision-making (Brown et al., 2021). We posit that a particular obstacle that prevents or mitigates sound circular decision-making (CDM) is that stakeholders dealing with CE may overlook the different quality levels of contributions to CE – or may lack decision-making support to navigate start-to-finish selecting the most impactful circular innovation to allocate resources to. Brown and colleagues (2021) support our argument, pointing to the current challenges of aligning circular innovation partners upon a shared circular purpose and the need for "developing a circular oriented value capture model focused on collective outcomes" (p.13).

Funding and policy support for circular innovation is often disproportional to the potential contribution of the innovation towards the transition to a circular economy – meaning, the innovations with the highest potential for circular impact are not necessarily the ones that receive the most support. The current way of decision-making can be counter-productive to CE because of its support for incremental innovation (Ritzén & Sandström, 2017). For example, accelerating and scaling up an innovation that uses a waste as an input to the business model further ingrains the production of this waste in the economy. "Business-as-usual" linear pathways are created through "sustainable" innovations that fit within this scheme and thereby further reinforce these existing path dependencies – meaning, while incremental change may offer small gains in sustainable practices, its adoption reinforces the current way of operating and presents another barricade for transformative innovation to overcome. This indicates a need for a change towards a different type of decision-making logic.

The main objectives of our work are to formulate a decision-making logic that helps in taking decisions, considering the quality of innovation circularity and its respective diffusion potential. We also aim to operationalize and verify the framework with a case illustration and by testing the applicability with scientists and practitioners, considering political and cultural context variations, as well as to present this logic in a way that it supports learning-by-doing and reflexivity.

5.1.4. Existing tools and current gaps

Some related tools have been developed for predicting or informing decisions with an environmental impact, but none currently exist to assist practitioners in *navigating* their decisions operationally. These static models or schemes often capture only a moment in time and consider only a single factor of a decision as the basis for evaluation (e.g., the

waste hierarchy); use inconsistent categorizations and terminologies, causing confusion amongst actors (e.g., the R-imperatives); or give a deceivingly precise quantitative result – when in fact many assumptions and estimations are put into the model – and do not allow the decision-maker autonomous operation [e.g., life cycle assessment (LCA)]. In the field of decision-making, the bounded rationalities and other challenges around environmental policy and practice uncovered in multi-criteria decision analyses (MCDA) lead to uncertainties, indicating a need for an input-responsive, flexible framework for decision-makers to reference and help elicit improved questions to ask and steps in the decision (Kalbar et al., 2012; Kalbar et al., 2016).

This gap between science and implementation in practice calls for a resource productivity-oriented framework (van Ewijk & Stegemann, 2016). Yet, the results of Zolfagharian et al. (2019) – an important assessment of 217 transition studies through systematic review – found that: "While current transition research is relatively strong in explaining past transitions and case studies, it seems less strong in designing (practical) interventions" (p. 11). To address the dilemmas in the transition to a circular economy raised by the WRP, and in response to the gaps in literature and calls from previous researchers in this paper, we offer a new circular decision-making logic for actors and organizations. To operate this logic, we have created an operational framework called the Circular Decision-Making Tree (CDMT). The CDMT builds on some of the existing commonly referenced frameworks as introduced in Table 6:

Table 6: Existing tools related to a circular decision-making logic, added value, and limitations

Tool/ approach	Primary added value	Limitations
Waste hierarchy	• Widely supported guide for waste management that (Dijkgraaf & Vollebergh, 2004) • Prioritizes waste treatment options to reduce environmental impacts in preferential order (Hultman & Corvellec, 2012)	• Offers limited specification, implementation of prevention, and guidance for choosing amongst the levels of the hierarchy (van Ewijk & Stegemann, 2016) • May result in stimulating optimization of the reigning linear economy (vs. fundamental change necessary for a new circular paradigm)
R-imperatives	• Illustrate hierarchies of CE value retention (Campbell-Johnston et al., 2020) • Frequently referenced as the "how-to" of CE (ibid) • Highlight the idea of value preservation or resource value retention options (Reike et al., 2018)	• Numbers, sequence, and terminology of these R-imperatives are inconsistent across frameworks, countries, and supranational organizations like the EU, the UN, and the OECD (Campbell-Johnston et al., 2020) • Contradictory syntheses of the R-imperatives built into complex political decision-making processes (Hultman & Corvellec, 2012; Reike et al., 2018)
Life cycle assessment (LCA)	• Analytical tool that captures the overall environmental impacts of all the life cycle stages associated (Finnveden et al., 2009) • Highlights potential environmental tradeoffs from one phase of the life-cycle to another, from one region to another, or from one environmental problem to another (Curran, 2014)	• Compares "either-or" decisions; generally not designed to help select from a larger pool of innovation possibilities (de Haes et al., 2004) • Does not give guidance through various steps of decisions (Finnveden, 2000) • User must already understand the environmental translation of the output value impacts, as well as when and why it would be appropriate to apply this tool (Curran, 2014)
Multi-criteria decision analysis (MCDA)	• Tool to discover and measure decision-maker considerations about various (mostly) non-monetary factors to compare alternative courses of action (Huang et al., 2011)	• Aims to model and predict the behavior of decision-makers, but lacks the capacity to help stakeholder navigate decision-making processes in real time (Smith, 1979; Groeneveld et al., 2017)

Still, a number of scholars have stressed the lack of appropriate CE tools and a shared language, such as in the context of CE-inspired business model innovation (Antikainen & Valkokari, 2016; Bocken et al., 2017; Lewandowski, 2016). We recognize both the value and limitations of the tools and frameworks in Table 6, and we build on these in the circular decision-making logic embedded into the CDMT that we offer in this paper. In the existing approaches, we note a lack of guidance amongst circularity levels, a scheme that encourages transformative practices over optimization, a shortcoming in clarity and consistency across a sustainability rhetoric, an assessment tool that does not require an extensive scientific background to understand, and a heuristic to aid in predicting decision outcomes. Thus, while significant research has been conducted in the fields of waste management, environmental assessments, and decision-making, there remains an interdisciplinary gap between science and practice.

Since we are still in a linear economy (LE) regime (despite increasing circular efforts), we often see decision-makers in CE taking the existing economy as the starting point and trying to incrementally improve upon that. Yet, this may become counter-transformative by enhancing path dependencies and lock-in of the LE. To break free from the currently prevalent path-dependent logic of decision-making common in business and policy, we argue in this paper to rather take the perspective of a radically different future with radically different assumptions that minimize extraction and consumption striving respect planetary boundaries – beyond which human perturbations risk destabilizing the earth system at the planetary scale (Steffen et al., 2015). For these reasons, we argue that there is a need to take on a different decision-making logic: a circular decision-making logic. This distinct logic is embedded in our CDMT framework, which evolves from addressing the WRP dilemmas in CE (for example, the unintentional reinforcing of linear pathways through attempts at circular innovation) and based on the identified need for a distinct type of circular decision-making. In the transition to a circular economy, we hypothesize that a tool offering navigation through circular decisions – based on this logic – can provide useful orientation on hierarchically preferable contributions to a CE and diffusion potentials, through its intended operational and applicable format across sectors and societal domains. Accordingly, this paper is guided by the following research question:

What kind of new decision-making logic is needed to address tensions and dilemmas that actors face in the transition to a circular economy?

5.2. METHODOLOGICAL APPROACH

To develop the CDMT, we first drew upon existing literature and frameworks, and we formulated an initial draft version of a circular decision-making framework. We then tested and refined this framework in a series of workshops and interviews, exploring the practical uses and added value for decision-making (rather than to find out whether it serves as a comprehensive algorithm). As our aims were more linked to bringing theory into action, we have selected a pragmatic qualitative methodology for our research. Pragmatism in transition research allows for more innovative research designs and methodologies for what fits best and posits that true theories are those which can successfully enable and support action (Zolfagharian et al., 2019), which matches with our research aim. Qualitative research has been deemed to be more suitable to handle heterogeneous and multi-level nature of transitions (Andersson et al., 2014; McDowall & Geels, 2017), so we have selected this methodology. In our qualitative methods, we took a four-prong approach:

First, we conducted a literature review (Snyder, 2019; Zolfagharian et al., 2019) to understand the current state of transition to a circular economy and what was lacking in science and practice. To form a solid theoretical and applicable foundation for the circular decision-making logic and corresponding framework, we reviewed literature around circular economy, decision-support tools, circular frameworks, environmental assessment methods and models, and national and international waste directives. This created our problematization and motivation for a framework to support in circular decision-making. The theory and frameworks analyzed were incorporated into the design of the CDMT to increase its internal validity (Drost, 2011). We developed the framework's logic building primarily on transition theory (see e.g., Elzen et al., 2004; Geels, 2010) and incorporating tools stemming primarily from the field of industrial ecology (see e.g., Ayres & Ayres, 2002; Deutz et al., 2015).

Second, we designed the CDMT. The construction and design of the CDMT involved: (1) synthesizing existing frameworks such as the waste hierarchy (Gharfalkar et al., 2015; Pires & Martinho, 2019) and R-imperatives (Campbell-Johnston et al., 2020; Reike et al., 2018); (2) embedding the tool in existing theory, such as strategic niche management (SNM) (Kemp et al., 1998; Schot & Geels, 2008), the multi-level perspective (MLP) (Geels, 2002; Smith et al., 2010), transition management (TM) (Loorbach, 2007; Rotmans & Loorbach, 2009), and technical innovation systems (TIS) (Bergek et al., 2008; 2015); and (3) selecting a decision tree format (Quinlan, 1996; Priyam et al., 2013) to design our new framework (for further details, see the following section). We validated the framework design and assumptions of the CDMT within our team to address research

quality, including validity and reliability (Drost, 2011), which we also explain in further detail in the following section.

Third, we conducted two successive focus group workshops in the Netherlands, in order to verify the operational logics of the framework with scientists and practitioners, guided by well-known approaches (Krueger, 2014; Parker & Tritter, 2006). This focus group workshop method was selected because "focus groups, together with other qualitative methods, provide researchers with additional means of acquiring rich, experiential feedback from service users. Moreover, the supportive, congenial, non-judgmental setting offered by the focus group enhances the likelihood of collecting the diverse and spontaneous opinions that elude the in-depth interview and the nominal group technique" (Powell & Single, 1996, p. 504). Informed consent was obtained from all participants to be recorded and to publish results in a scientific journal. The recordings of the workshops were saved and stored on a secure computer.

The workshops were conducted online and video recorded. They took place in April and September of 2020, respectively, and had a scheduled duration of 2.5 hours each. In our research, we adopted principles of collaborative knowledge production in participatory processes, so the workshops were not a unilateral source of data collection; but rather, they had an element of co-design with participants – wherein they critiqued and informed on the framework constructs. Thus, after the workshops, we made some minor adjustments to the original CDMT in line with participant feedback and finally created the refined CDMT presented in this paper. After the workshops, results were also shared back to participants.

In the first workshop, seventeen stakeholders from policy, research, practice, and government participated in the two workshops. Here we unpacked implicit risks, hampering factors, tradeoffs, and organizational dilemmas that factor into circular decision-making. In the first workshop, we presented to the groups the premise for the CDM and CDMT, based on our project context and the WRP conceptual framework. The floor was opened for question-and-answer sessions, and then two breakout groups were formed. In the second workshop with similar participants (in terms of numbers and fields of expertise), we investigated the CDMT's usefulness to stakeholders and the soundness of its internal logics. We exemplified the pathways of the CDMT stepwise, illustrated with a case on plastics. After the initial introduction to the tool, participants joined working groups to explore and discuss the tool individually and collectively. Strengths, weaknesses, and limitations of the presented framework were identified as well as key aspects of usability for different stakeholder groups were identified. Notes

were taken to create informal transcriptions in the breakout groups by an assigned note taker and by us during the plenary for cross-referencing verification.

In the analysis, we heeded Parker and Tritter (2006)'s warning on focus group methodology: "Attention must be paid to the dynamic aspects of interaction within the group, for it is this dynamic nature which is at the heart of focus groups and which endows them with the power to generate insight often negated by other methods" (p. 35). For example, when one participant would make a statement, we also noted reactions to this – for example, of head shaking in disagreement, affirmative "Mhm"s, thumbs up emojis sent to the group through the video platform as responses, and other body language indicating the strength of the group's consensus around a particular statement from a participant or moderator. Due to the format of the workshops, we understood that there would be a lot of complexity not captured in a coding software during our analysis. The non-verbal forms of communication would have gone under the radar unaccounted for by a coding software, missing important qualitative data. As Maykut and Morehouse (2002) argue: "A qualitative researcher learns about significant aspects of reality by indwelling in these complexities. These complexities, as Lincoln and Guba state, cannot be figured out, cannot be understood by one-dimensional, reductionist approaches; they demand the human-as-instrument; they demand indwelling. To restate, the human instrument is the only data collection instrument which is multifaceted enough and complex enough to capture the important elements of a human person or activity" (p. 25). For this reason, we employed the human-as-instrument method (ibid; Guba & Lincoln, 1982), using informal analogue coding for themes in responses.

Fourth and lastly, we replicated these workshops in other global contexts to test and strengthen the reliability of the tool, and to explore its potential for application in multiple contexts. The CDMT was originally developed in and reflected upon in the Dutch context, as a part of the Waste FEW ULL project funded by NWO (Dutch National Science Foundation), the European Union's Horizon 2020 program, and the Joint Programming Initiative (JPI) Urban Europe. Within this project context, we worked with project partners across three continents and four countries with the aim to "reduce waste inefficiencies". In a collaborative undertaking with our international project partners in Bristol, UK; São Paulo, Brazil; and Western Cape, South Africa; we tested the logics and tool in each distinct geopolitical context with a group of local stakeholders in each location, led by our project partners in that region. These contexts were selected for their involvement through the Waste FEW ULL project, but importantly – also for their differences in and diversity of circularity challenges, material stocks and flows, and

governance contexts, in order to see the generic ability of the decision-making logics and tool to be robust in these different contexts.

To approach the development of a multi-contextual framework, we reflected upon stakeholder feedback from both the Global North and Global South, synthesizing and integrating the feedback from participants to improve the logics, usability, and mapping of the tool in their respective contexts. We created a replicable reporting template for consistency of results reporting across country contexts. Each of the four investigative groups from Global South and Global North reported answers through the reporting template, the results of which were synthesized into a table of international reflections on the circular decision-making logics and feasibility of application in practical contexts. A total of n=50 stakeholders reflected on the internal circular decision-making logics and the applicability of the CDMT. In all contexts, a combination of researchers and practitioners working on topics related to the circular economy gave feedback on the logics and design of the CDMT. To guide the discussion, the following guiding questions were used as prompts, replicated in each of the four contexts:

- *Are there uncertainties, paradoxes, and dilemmas of decision-making that you consider barriers in the transition to a circular economy? What examples have you come across in your work or other area of activities?*
- *Do you agree with the internal logics of the CDMT? (What would you add or adjust for better usability?)*
- *(How) and for whom could the CDMT's procedural logics support decision-making?*
- *What (if any) is the added value of the CDMT in helping distinguish innovations with higher-level contributions to a circular economy?*

The rest of the paper goes as follows: in section 3, we discuss the theoretical basis for the CDMT and its design; in section 4, we explain the CDMT's steps and flow. In section 5, we report the feedback from the focus group workshops. In section 6, we discuss the results of our study, including insights gained through the study, limitations of the study, and future research recommendations stemming from our work. Finally, in section 7, we end with concluding remarks summarizing our work and offering a short reflection on its contribution to science and practice.

5.3. CDMT CONSTRUCTION AND DESIGN: THEORETICAL BASIS AND VALIDITY

The CDMT presents a framework that is organized in three sections (operational, strategic, and reflexive). Within each section we identify concrete steps and, accordingly, decisions that may lead to the best possible steps to support a transition to circular economy. In defining the steps of the CDMT, our theoretical assumptions underlying the framework were informed by aspects from the following theories: SNM (Kemp et al., 1998; Schot & Geels, 2008), the MLP (Geels, 2002; Smith et al., 2010), TM (Loorbach, 2007; Rotmans & Loorbach, 2009), TIS (Bergek et al., 2008; 2015), and the WRP (Greer et al., 2021). We critically reflected upon existing tools presented in the literature such as the waste hierarchy (Gharfalkar et al., 2015; Pires & Martinho, 2019), the R-imperatives (Campbell-Johnston et al., 2020; Reike et al., 2018), and environmental impact assessment (EIA) (Glasson & Therivel, 2013; IAIA, 2009). The steps in the CDMT are based on a CDM logic, which relates to a new economy paradigm: wherein transformational decisions are made for a radical new way of operating in society, rather than operationalization of (i.e., improvement of the existing) the linear economy and its inherent processes. In line with two fundamental principles of CE, the CDM logic prioritizes first the least virgin material extraction from the earth possible, followed by a cascading order of highest possible value retention of materials already in the system. The decision-making framework presented is built with this CDM logic as its backbone, and is created for practitioners to reference, in order to ideally make stronger and more transformative changes.

The development of the CDMT is framed at least in part by theory from transition scholars Bergek et al. (2008; 2015), who identify in their TIS theoretical framework different types of systemic problems that can block the anchoring or widespread adoption of innovations. For example, actors' problems may be capacity-related: actors may lack competence or capacity to learn or utilize available resources, to identify and articulate their needs, and to develop visions and strategies. Institutional problems may also be capacity-related, for example, when the institutions themselves are weak. Interaction problems may be presence-related, if interactions are missing because of a cognitive distance between actors: differing objectives, assumptions, capacities, or lack of trust. Infrastructural problems – referring to physical, knowledge, and financial infrastructure – may be quality-related: when an infrastructure is inadequate or malfunctioning (ibid; Wieczorek & Hekkert, 2012). Through the framework of the CDMT, we aim to address these actor-related, institutional, and infrastructural problems identified by these authors.

Also central in the development of the CDMT is TM, a field of theory describing a governance mode based on complexity and with the goal of navigating the governance of long-term change processes towards more sustainable societies (Loorbach &

Rotmans, 2010; Rotmans et al., 2001). Transition management deals with "key elements related to long-term governance of complex societal processes: multi-actor, long-term goal setting, innovation, evaluation and adaptation and knowledge transfer and learning" (Loorbach, 2007, p. 79). These elements are also key pieces of the CDM logic that deals with innovation and adaptation. TM – like circular decision-making – is a highly uncertain and sometimes chaotic process. Based on this understanding and grounded in this theory, the CDMT is not designed to be prescriptive in nature to calculate an exact output; rather, like TM, one of the CDMT's primarily functions is as "an attempt made to link different actors and organizations with different time horizons, ambitions, and values… [and] a way of indirectly influencing, adjusting, redirecting, and guiding actions" (ibid, p. 79). The CDMT was designed to support in directing decision choices and to help in guiding action during circular decisions.

The framework guides decision-makers to consider options in the sequence from most circular to least circular. In this way, the framework takes advantage of the common tendency for decision-makers to not consider all options but to satisfy, that is, choose the first option that reaches a satisfactory aspiration level. In contrast, sequencing in a framework can be defined as "planning a sequencing or deciding how to select the next task" (Baker & Trietsch, 2013, p. 2). Searching through options in sequence from the innovation with the highest-quality circularity and diffusion potential increases the likelihood that a more circular option is chosen (as compared with the opposite or a random sequence), so we have incorporated this heuristic principle into our framework.

To maintain the tool's straightforwardness while accounting for factors outside of its immediate focus, the CDMT directs the user to a complementary tool at a decision point when the expertise becomes out of the scope of the heuristic. For example, when the decision-maker is unclear on what would be a more sustainable material to substitute for the current waste stream, the user is directed to an LCA. When considering uncertainty in cost-effectivity, the user is directed to a related tool, e.g., a cost-benefit analysis (CBA). It is our opinion that referring to other frameworks such as these can allow the tool to keep its visual simplicity while offering important information beyond the CDMT's main focus of differentiation, potential impact on the transition to a circular economy. The CDMT and embedded decision-making logic was designed to be generic, independent of certain sectors or material types, and applicable across various geopolitical boundaries. It outlines a multitude of possible decision point uncertainties, answers, and resulting pathways that an actor may come across when operating on circular decision logics to help decision-makers navigate the process from start to finish.

The framework is broken down into three main columnar sections, grouped according to logical chronological order of steps to consider during a circular decision:

5.3.1. "Operational" CDMT Column 1

The first column addresses the chronologically first and "Operational" aspect, i.e., the initial innovation conceptualization, design, and production before scaling. The tool is designed so that the higher up on the tree the innovation ranks, the higher circularity potential it has. The framework bases its first column on other established circular economy tools, such as the waste hierarchy and R-imperatives discussed in the introduction. The CDMT matches these tools in indicating the same optimal result and similar preferences of cascading circularity quality. These other tools only miss indicating directionality in decision choices – here, the CDMT directs the user to consider the possibilities from the best option down, rather than simply "improving" environmental desirability from the bottom up. We integrated this highly relevant aspect based on conceptual research that described the importance of preventing undesirable and unsustainable dilemmas that may result from turning a waste into a resource, described in the literature as the WRP (Greer et al., 2021). Once a choice between circular initiatives is made, the user advances to the second stage.

5.3.2. "Strategic" CDMT Column 2

The second and "Strategic" column prompts the decision-maker to examine the selected circular innovation's diffusion potential, going beyond considerations of the innovation in isolation, and it focuses on the selected diffusibility and scalability potential. The CDMT encourages the decision-maker to consider deeper questions about the innovation's scalability, replicability, and diffusibility: important factors into an innovation's potential impact on circular economy beyond the local. This component includes considerations of economies of scale, capital gains and financial feasibility, and the possibility of scaling in another cultural, political, social, or economic context. The CDMT's second column's theoretical underpinning stems from transition sciences: particularly, Strategic Niche Management and the Multi-Level Perspective, and with considerations from innovation diffusion theory as related to sustainability transitions (Rogers, 2010; Boons et al., 2013; Loorbach et al., 2020). The "Strategic" column, as the name indicates, mirrors principles of strategic niche management (Kemp et al., 1998; Schot & Geels, 2008). This is foundational literature describing the process for scaling up or diffusing a niche innovation to a regime level (the use of which concepts inherently embeds the MLP in our theoretical framework). In SNM, first, an innovation is chosen (akin to our column 1). Then, the environment for diffusion is examined and selected, similar to the column 2 constructs of the innovation scaling up in its current or another setting. Finally, the implementation is planned, examining resources in possession and needed, likening to the other constructs from column 2 that examine cost-effectivity and the ability to acquire additional resources. The steps of the Strategic column of the CDMT are also echoed more recent literature; for example, von Wirth et al. (2019)'s research on the types of diffusion, including scaling

(vertical diffusion) by growing internally or translating (horizontal diffusion) in other contexts. In this way, validity is taken into account with the constructs of the Strategic column by relating them to existing transition theory. In our research, we build on this and add to it by offering some potential answers or recommendations to alternative and complementary tools, to address some of the critiques and limitations of these theoretical frameworks.

5.3.3. "Reflexive" CDMT Column 3

Because of the importance of reflexive learning in the continuous progression towards a circular economy, the third and final "Reflexive" column prompts the user to evaluate and monitor the impact of the innovation selected. This includes identifying key factors and indicators to evaluate the impact of the circular innovation. After this assessment, the user may repeat the analysis for further material and energy flows. This evaluation and monitoring step brings the decision process full circle, concluding with a component of reflection for future learning. Having taken a transition lens in our paper and to construct the CDMT, we have assured for the validity of the final Reflexive column by embedding these final constructs in foundational transition management literature. It is well-established in TM theory that continuous evaluation and monitoring is a vital part of the transition process (Kemp & Loorbach, 2006; Loorbach, 2010), and for this reason, it forms a necessary core part of the CDM logic as well.

How should we evaluate and monitor then? One prominent tool from industrial ecology is the Environmental Impact Assessment, which has been shown to be helpful in decision-making and is defined as "the process of identifying, predicting, evaluating and mitigating the biophysical, social and other relevant effects of proposed development proposals prior to major decisions being taken and commitments made" (IAIA, 2009). Appropriately, we incorporated related elements of the EIA into the final constructs of the CDMT: "The identification of the main impacts brings together the previous steps with the aim of ensuring that all potentially significant environmental impacts (adverse and beneficial) are identified and taken into account in the process… The prediction of impacts aims to identify the magnitude and other dimensions of identified change in the environment with a project/action, by comparison with the situation without that project/action… Auditing follows from monitoring. It can involve comparing actual outcomes with predicted outcomes, and can be used to assess the quality of predictions and the effectiveness of mitigation. It provides a vital step in the EIA learning process" (Glasson & Therivel, 2013, p. 5). Yet, an EIA is traditionally a quite formal, large-scale (e.g., bridge construction), and often rigid impact assessment. Thus, we draw from this analysis structure, integrating some key components of the EIA in the CDMT, while offering a less rigid evaluation and monitoring process for the likely smaller-scale innovations that could be considered when applying the CDMT.

5.4. CDMT STEPS AND FLOW

In this section, we explain the steps and flow of the CDMT, as well as how a decision-maker might walk through the framework to select a circular innovation to support with the highest potential for impact. See Figure 7 below to follow the illustration.

5.4.1. "Operational" column: Innovation prioritization

1) Dematerialization: When comparing existing or potential initiatives to support within the circular economy, one would address the possibility of dematerialization, i.e., reduction of the amount of material required for a product or process (Thomas, 2003). Dematerialization is positioned first in the CDMT because reducing material use to preemptively prevent waste production is overwhelmingly the most efficient pathway to overall waste reduction from a product or process (Bizcocho & Llatas, 2019; Cleary, 2014; Gentil et al., 2011).

2) Material substitution: In the hypothetical scenario that no projects or innovations related to dematerialization are proposed, the user consider the possibility of material substitution: substituting in a suitable alternative material with a lower negative environmental impact intensity while fulfilling the same function (D'Amico et al., 2021). If the potential for better material substitution is unclear, the CDMT directs decision-makers to the appropriate tool for the situation to inform the decision at the current stage: in this case, an LCA. If neither is possible, a more favorable material mix – i.e., a combination of a partial amount of the currently used material and an environmentally favorable material – is then suggested by the CDMT.

3) Material recovery and reuse: If material substitution is not a viable route, the next alternative following the flow of the CDMT is to close loops through (waste) material reuse. Second-hand material cascading is a valuable initiative temporarily, but it is not transformative if the material production remains the same. Optimization can improve the current linear system, but it does not create a fundamental change towards an institutionalized alternative practice – which is why it is positioned as a lower alternative in the tree.

4) Cascaded recycling, open-loop recycling, or down-cycling: If none of the aforementioned options are considered viable possibilities within their context, only then should the lower-value repurposing (e.g., recycling) be selected as the path forward. These innovations are tricky and placed last because of the potential to reinforce demand for a waste described by the WRP, furthering lock-in and optimization of the linear economy regime in place.

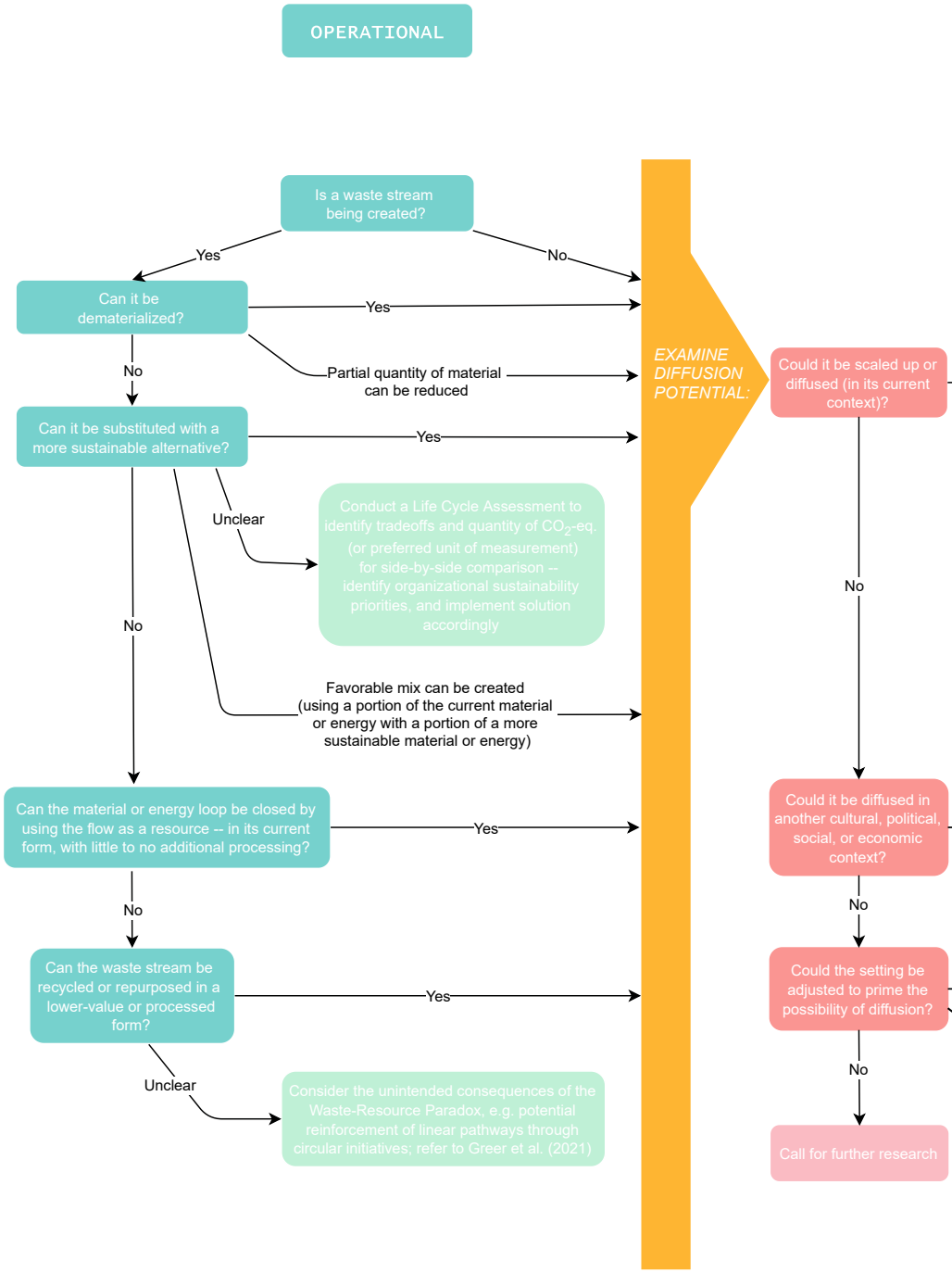
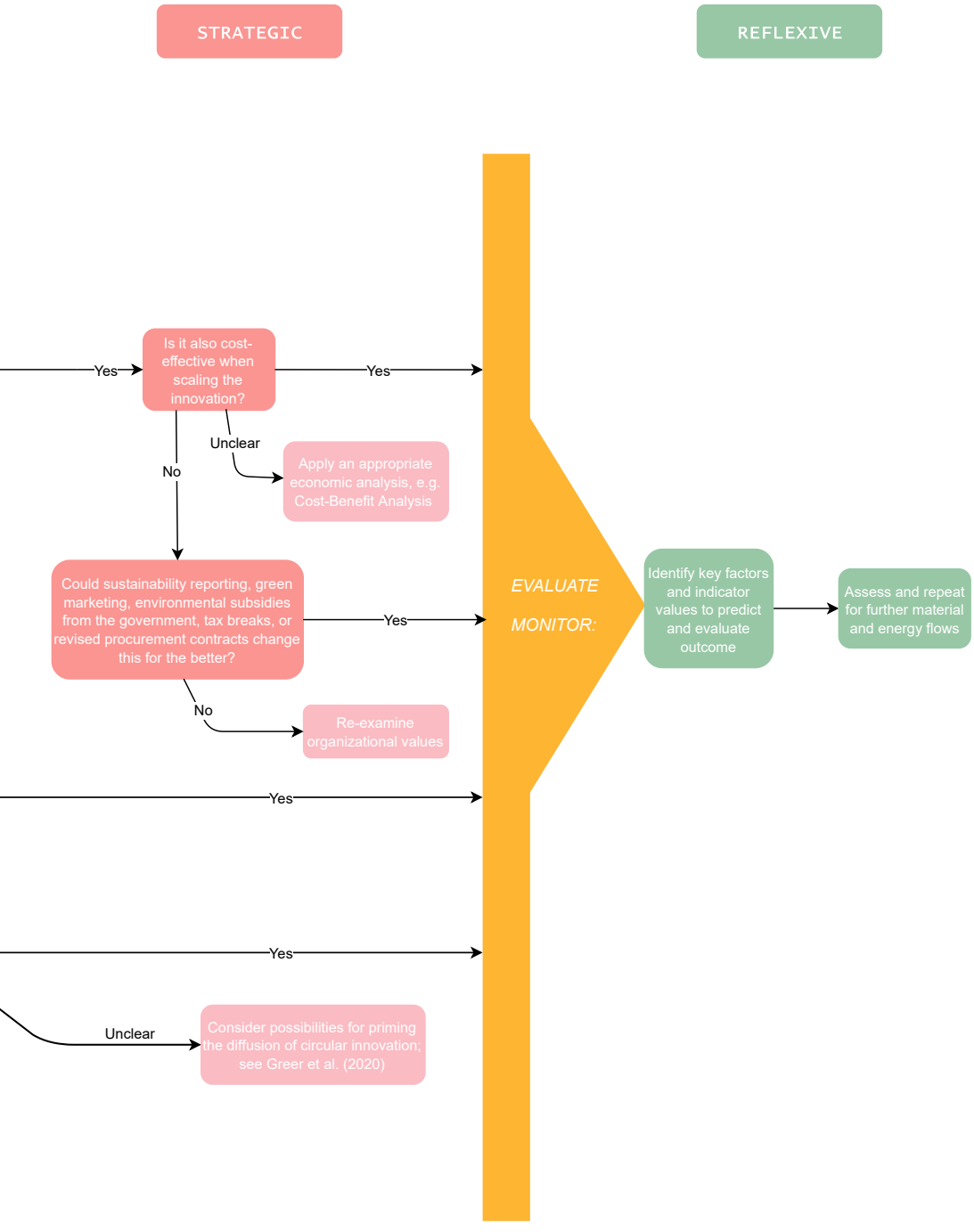


Figure 7: The Circular Decision-Making Tree (CDMT)


STRATEGIC
REFLEXIVE
Yes
Is it also cost-effective when scaling the innovation?
Yes
Unclear
Apply an appropriate economic analysis, e.g. Cost-Benefit Analysis
No
Could sustainability reporting, green marketing, environmental subsidies from the government, tax breaks, or revised procurement contracts change this for the better?
Yes
No
Re-examine organizational values
Yes
Yes
Unclear
Consider possibilities for priming the diffusion of circular innovation; see Greer et al. (2020)
EVALUATE
MONITOR:
Identify key factors and indicator values to predict and evaluate outcome
Assess and repeat for further material and energy flows

5.4.2. "Strategic" column: Diffusion and acceleration potential

Once a proposed circular innovation is selected from the first column, "Strategic" considerations for the proposed innovation's potential for diffusion are necessary to examine to understand its potential for more widespread impact.

1) Scaling or diffusing in current *context:* Here, capacities for and limits to growth are analyzed. In principle, the most desired innovation is the one with highest-quality circularity, paired with highest diffusion potential. The user would first consider diffusion potential in the innovation's current context. In the case that constraining factors are too great to scale up in its current context, one would move to the next consideration: the same innovation, scaled in another context.

2) Scaling or diffusing in a different *context:* Here we also consider availability levels of non-financial resources of the selected circular innovation, but in another context. Might another cultural, political, social, or economic setting allow for room for diffusion that the current context does not? The answer to this determines the next step taken.

3) Adjusting the settings and conditions within the context to favor diffusion potential: If more favorable contexts for diffusion of the selected circular innovation do not currently exist, might they be created or facilitated? In that case, the CDMT refers the user to 15 practices and principles for connecting niche innovation with regime organizations by Greer et al. (2020). For example, "empowering actors to pursue alternative sustainable pathways" and "top-down influencing" may be applicable in this case as well.

4) Cost-effectivity of scaling: This step does include economic considerations to add a piece to the picture of the scalability on a larger level. It is not a comprehensive check on economic viability directly within the tool. That level of economic detail is outside the scope of the tool, whose primary focus is on the material and energy aspects of decision-making outcomes.

5.4.3. "Reflexive" column: Monitoring and evaluation of implementation

The last phase of the CDM logic is incorporated for thoroughness and to set a baseline for evaluation and monitoring of the intended and actual impact of the innovation. In this step, key factors and indicator values to predict and evaluate the outcome should be developed. After a predetermined set of time, e.g., one year, of implementation of the initiative or innovation in practice, the innovation's true impact over time should be assessed based on the designated criteria. Finally, after evaluation of the particular material at hand, the circular decision-making logic indicates to assess and repeat the exercise for further material and energy flows in this and other sectors of interest.

5.5. REFLECTIONS ON THE CDMT

Now that we have illustrated the circular decision-making logics, we shortly describe the state of CE in the different verification contexts and report on the results of the applicability workshops.

5.5.1. CE in international contexts

As part of the research project Waste FEW ULL, we teamed up with international colleagues to conduct workshops and groups interviews with stakeholders in their local contexts addressing waste inefficiencies and circular economy in the Netherlands, United Kingdom, South Africa, and Brazil. These countries are all on different pathways towards circularity, as summarized below:

Netherlands: Among diverse countries that have committed to CE targets, the Netherlands is a prominent pioneer in the pushing of circular economy (taking substantial steps towards their stated goal of full circularity by 2050) (Rijksoverheid, 2021). As supported by reports from the Netherlands Environmental Agency, a more ambitious CE transition towards substantially lower resource and material consumption and less generation of waste should be "based on high-circularity strategies, such as smarter manufacturing and use of products, and extending the lifetime of products and product components. Recycling alone, and low-grade recycling in particular, is still closely related to a linear economy" (PBL, 2017, p. 7). Despite the clear vision of preferred pathways in the Netherlands, circular targets are still failing to be met (PBL, 2021). The struggle of a frontrunning country in circularity, like the Netherlands, to meet targets indicates that our current strategies in decision-making around amplifying the circular economy are not effective in a meaningful enough way.

United Kingdom: For the past 3-4 decades, the UK has been progressing in its efforts towards the transition to a circular economy; however, the policy translation of these ambitions differs between its four countries. Some academic institutions, think tanks, and leading businesses have built on the foundations provided by European policy to raise awareness of the circular economy concept, bringing a more holistic approach to the various interpretations of the CE discourse. Whereas initiatives in waste management policy here were formerly concerned with end-of-pipe solutions, there is a recent collective change in understanding that keeping resources in productive use is the responsibility of both the producer and consumer, in a systems thinking approach to the problem (Hill, 2016).

South Africa: In practice, large volumes of valuable resources are transported to landfill. Sorting does occur at landfill, but the externality cost and access to these resources

are lost to local inhabitants. There are opportunities to improve circularity, but conventional practices dominate, and there appears to be limited scope in policy and practice to intervene. Local authorities are largely overwhelmed by the scaled volume of waste, are under-resourced, and do not have the capacity to change the course of a conventional approach to a more circular practice. A hinderance to circularity in the South African context includes the inability to implement policies and interventions to divert food waste and organics from landfill. It is a combination of many factors that fail to transform the current trajectory: lack of leadership; establishing policy adds benefit to the waste and recovery value change; lack of constructive and cooperative partnership between local authority, private sector, and non-government organizations (Rodseth et al., 2020; Mativenga et al., 2017).

Brazil: In Brazil, there are some widespread grassroots initiatives but lacking infrastructure for sustainability transitions. Currently, it is important to invest time in informing decision-makers about waste reduction and management practices. From a national perspective, there is still a lack of dissemination of sustainable innovation-based practices and technology adoption, as well as an absence of funding incentives for small producers. Current living lab projects are interesting and helpful but have a limited timeline and therefore a limited impact. Professionals involved often lose information and do not have access to possible technologies that could be implemented. The interaction between academia and public sectors is far from perfect due to this lack of information between institutions (Guarnieri et al., 2020; Paes et al., 2019).

5.5.2. International critical reflections and insights

The results of the workshops and group interviews in the Dutch, UK, Brazilian, and South African contexts, designed to test and validate the CDMT's reliability in multiple distinct contexts, offered feedback on the usability and internal logics of the decision tree. It was discussed if and how the circular decision-making procedural logics could support decision-making in practice and its potential application contexts as a guiding scheme. These full results are detailed below in Table 7 and are summarized thereafter:

Table 7: Verification of the Circular Decision-Making Tree in four global contexts

CDMT verification			
Context	**Participants involved**	**Valued functions/Perceived assets of the tool**	**Critical reflection/feasibility**
Netherlands n=17	• Researchers in academia • Think Tank / Researchers in practice • Consultancy • Policymaking	• Accurately reflects decision points and uncertainties in practice (consultancy and policy) • Useful when communicating/interacting with suppliers, as a way to evaluate circularity impact with a common frame of reference • Flexible in ability to apply when drawing up contracts (project leaders could raise these issues and target specific questions to relevant people) • Challenges incrementalism and encourages more transformative decisions	• Trade-offs (e.g., with energy) and further system changes to be expected • In an architechtural or urban design context, it might be hard to ever say yes to the questions • Best applied at a high/management level • Outcomes directly leading to circularity are not guaranteed
United Kingdom n=11	• Researchers in academia • Policy • Activism / Non-profit • Civic entrepreneurship • Community co-operatives	• Emphasizes the hierarchy in often-overlooked differences in contribution to CE • Creates a "CE architecture": ability to articulate between systems, boundary object role • Added value may also be theoretical, demonstrating the need for more inter-sectoral or collaborative decision-making that goes beyond individual organizations	• Single waste-stream focus • Entropy increases challenges in using the tool, because dispersed or mixed waste streams will be harder to address, e.g., smart phones with many components • Assumes upscaling is a goal, which it may not always be
South Africa n=4	• Municipal waste management • Provincial government • Policymaking • Living lab management and academia	• Directs decision-makers to collect more data or to be prompted for existing evidence • Alerts decision-makers to be more critical in the evaluation of the flow and implications • Provides understanding and awareness about mechanisms for implementation and upscaling • Very useful if stakeholders are involved in the process and are able of participate freely in the development of decisions	• Might be missing crucial steps that give or improve the evidence that is necessary for decision-makers • Could propose mechanisms for implementation and upscaling • Uncertain what tools could be put in place to enable the "Further Analysis" section that could support an enabling process to map the acceleration potential

Table 7: (Continued)

CDMT verification			
Context	**Participants involved**	**Valued functions/Perceived assets of the tool**	**Critical reflection/feasibility**
Brazil n=18	• Policymaking • Food technical production • Ministry for Agriculture and Food Supply • Non-profit • Researchers in academia	• Fills a gap for a management tool lacking in current practices, especially at the ministry level • Offers alternative to current majority bottom-up, chaotic planning by integrating increased rationality and structure in problem-solving • Locates interested parties and plans the strategy for good management of processes by mapping all working fronts from the beginning • Supports public policymaking and implementation and increases better time management performance by structuring next steps in user's current work	• Could be built upon and adapted for other links in the value chain • Effects of waste treatment and processing not captured • Future developments of the tool could include a typology of characterization of waste • Many decisions depend on the technological trajectory • Socio-political definition of responsibilities for waste disposal is a factor
Across all contexts n=50	• **All of the above**	• **Convincing consensus on structural logics (of a new perspective on sustainable practices and strategic planning)** • **Helps broaden vision outside daily practices, encouraging systems thinking outside one's immediate sphere** • **The internal logic supports problem framing around the quality of circular interventions. Helps identify dilemmas and paradoxes** • **Follows a logical path and draws attention to upscaling (to know what technology should be used and the viability of the innovation)** • **Catalyzes important reflection exercises and discussion on circularity processes and principles at multiple layers of companies, between and within public departments**	• **Should be paired with cost/benefit analyses within the status-quo of markets (account for capital, value distribution, return on investment)** • **An accompanying sectoral example makes logics clearer** • **Does not account for regulatory patterns on waste treatment** • **Power relations between actors, managers, companies, and waste management contractors are large and diverse**

In summary, the Dutch workshops indicated an accurate reflection of decision points in the CDMT, its challenging of incrementalism, and its usability in communicating across supply chains or when drawing up contracts – the lattermost particularly supported by Dyer et al. (2021), who underscores the importance of common interests, values, and priorities that in turn can contribute to a participatory design of a circular economy. The UK workshops observed the heuristic as a "CE architecture," with potential to act as a boundary object for the user to articulate between systems. In South Africa, it was noted to offer autonomy and facilitate co-creative decision-making at micro-, meso-, and macro-levels. The Brazilian stakeholders indicated potential as a management tool and as a complementary alternative to more common bottom-up approaches.

An important critical reflection related to economic influences not being at the forefront of the tool's guiding logic, since all decisions in reality are embedded in market and socio-economic contexts that deal with tradeoffs and challenges. The CDMT in its current state also does not include the influence of regulatory patterns on waste treatment or power dynamics. These remarks should be further addressed in later versions of the tool, which would be interesting additions, but were outside the scope of this research. In its current state, the participants in all four contexts indicated that the circular decision logics may aid in procurement decisions, create awareness in suppliers of such circularity questions, catalyze reflexivity about the diversity of circular options, and identify dilemmas while drawing attention to the impact of upscaling. According to the participants, the CDMT may be useful at multiple layers of society – providing a common understanding of shared values, more clarity on the shared meaning of circularity, and the implementation practices needed to select, support, and carry out circular initiatives within their sphere of influence – for firms and companies, industrial symbioses, general policy, and sustainable entrepreneurship. From the results of the workshops and interviews, we see certain functions the tool as being validated in a promising way. At the same time, we consider the critiques based upon which we offer recommendations for future in the following section.

5.6. DISCUSSION

5.6.1. Reflections on results

Through the participatory feedback from workshops, we learned that different actors were prone to follow the steps of the CDMT with differing degrees of rigidity. While some participants indicated that the framework functions literally to identify a circular innovation or policy to select based on the quality of circularity and diffusion potential, it was suggested by others in the workshops that it would serve best in practice as a discussion tool or meta scheme: to catalyze circular thinking within and across

departments or supply chains, to help strategize innovative priorities, and to co-create and build discussions around the steps involved in circular decision-making posed in the tool.

Strengths of the tree named in the focus groups include revealing the trap often surrounding the WRP (when a demand is created for a waste, thereby reinforcing the waste production, and sometimes monetizing it), helping to avoid or prevent this reinforcement of waste production. The decision tree discourages these linear economy optimizations that may also reinforce the path dependencies and inertia for the current linear economy regime. The CDMT presents a structuring and logic of circular decision-making, which re-orients a decision-maker who might otherwise make decisions that optimize and reinforce linear economy. In this way, it is representative of a new logic and improved steps in circular thinking. The 126-study analysis on thematic research areas of circular economy by Hina et al. (2022) indicated that "time, manager's interest, information and employees' awareness have been recognized as resources for Circular Economy Business Model implementation" (p. 11), a gap in knowledge about which the authors recommended be addressed. Based on the findings from our study, we suggest that the application and utilization of the CDMT in practice might be one answer to address this gap by increasing information exchange, aligning values, and raising awareness about the highest-quality contributions to a circular economy. The results of our workshops indicated that CDMT could also act as a boundary object for different actors in decision-making collectives, which may help reduce fragmentation across disciplines and create a common framing for scientific dialogue.

This exploratory study on the CDMT showed us that the tool is also not without its contestations. It does not offer a comprehensive economic analysis, as some participants from the workshops suggested should be the most important consideration. Interestingly, the most commonly used existing circularity frameworks also miss these economic aspects, so we consider the CDMT as the next developed step by helping to operationalize preferred pathways and addressing acceleration potential. One of the assumptions of the application of the CDMT is that the user is looking for the highest-quality circularity innovation. So, while the CDMT might assist in business model creation, it is not a recipe for this. It is designed to help the user who prioritizes circularity – and also does incorporate economic considerations – but it is not designed to select the most profitable innovation that may still be considered circular. We recognize that this may make it less popular in practice, in the still highly linear profit-driven economy regime. Still, as resources decline and virgin material costs rise, it may become ever more important to consider circularity as a top priority, and it could be economically beneficial over the long term to be a circular frontrunner in this regard.

Similarly, discussions on the processing of waste affecting social implications for the positive or negative, for example, were not addressed in this first version of the tool. Holtz et al. (2015) state that "a single model therefore can hardly achieve the goals of completeness and detailedness" (p. 50). This is due to the tradeoff between generality and context specificity of real-world transitions in models and frameworks, identified for example in theoretical literature on transitions by McDowall and Geels (2017). The CDMT was designed to cut through complexity to assist and guide its users through circular decisions. In simplifying some aspects of the decision, some factors have been condensed or left out. This was an intentional decision during the design of the tree, because incorporating too much complexity into the tool would eventually render it unusable. This condensing and simplifying of included considerations is always necessary for the first versions of tools and frameworks (McDowall & Geels, 2017; Scott, 1998), so further variables or social considerations should be taken up in a future research agenda. To offer increased transparency, aspects that have been excluded from this first version of the framework can be found in the appendix.

For example, chemical waste is not directly considered in the CDMT. We found this to be less directly relevant for this first, more general CDMT design. However, this might be a critical factor for those working in the chemical field. Thus, we direct users to first examine the tool and its related assumptions to determine if it is appropriate in their sector before implementing it in their field. We also believe that future researchers can build on our 1.0 version of the CDMT. This might include experimenting with more depth in the economic consideration of the tree, or dissecting the Reflexive column of the tool: questioning in what contexts can key factors be identified, and examining if and how scenarios be constructed. Relatedly, we recommend researchers to test the CDMT in various sectors and fields, who may build on our work by adopting this general CDMT and adapting it to include pertinent variables to their respective fields. Future researchers might develop industry-specific adaptations of the CDMT answering, for example, what secondary resource use would help their particular industry co-evolve toward circularity and sustainability.

5.6.2. Limitations and potential for future research

Our research was not without its limitations. For example, the workshops were replicated in four different contexts – but due to external factors, they were not exact copies of each other, e.g., in number of participants. These factors included the COVID-19 pandemic (no traveling was possible, so we could not do the empirical work and on-site observations as we had hoped), language barriers (the Brazilian focus group workshop was conducted by our project partners in Portuguese, who also translated the CDMT to Portuguese for this purpose – we authors could not personally present

in this setting because we do not speak Portuguese), and what can be named issues of social justice (actors in the Brazilian and South African contexts had primarily poor access to high-speed internet, which limited the number of possible participants). In line with our pragmatic approach, we do not make conclusive statements about the generalizability or applicability of the CDMT in multiple socio-geopolitical contexts. Yet, the results do present some evidence that the CDMT might be useful in various distinct contexts. Even with less than perfect replication of settings, we were able to gain local insight in various distinct contexts, which we believe still serves to improve the reliability factor of the CDMT.

In our analysis, we employed the human-as-instrument method – which we believe was preferable to a coding software, for the ability to pick up on crucial non-verbal communication – but there is the possibility for human error or bias to enter here. While we tried to be as objective as possible, it is important for the reader of the study to keep in mind. This can also be said for the influence of some participants on others during the focus groups: "Doubts exist about the extent to which both the moderator and the 'group effect' influence individual participation in a focus group discussion. A comparative advantage of the focus group, however, is its ability to enable researchers to identify quickly the full range of perspectives held by the respondents. Moreover, the interactional, synergistic nature of the focus group allows participants to clarify or expand upon their contributions to the discussion in the light of points raised by other participants, thus expanding on contributions that might be left underdeveloped in an in-depth interview" (Powell & Single, 1996, p. 504). In choosing the methods for our study, we expected that the results gained from a fruitful group discussion would outweigh the risks of this workshop approach.

The CDMT tool itself may have practical limitations, since some decision-makers might still not know the answers to some of the questions posed in the framework. Even when all choices and information are clear, decision-makers may still be unable to implement its logics in practice – based on path dependencies, vested financial interests, power dynamics, or contractual obligations. These dilemmas are characteristic of most desired sustainability transitions, and they are difficult to overcome. That said, what we offer in this paper is one tool that may assist decision-makers in more carefully considering and navigating through tensions and dilemmas that decision-makers in a circular context may experience. In its first form presented here, the CDMT may offer more conceptual insight and awareness about quality of circularity and diffusion potential. Additional contexts for applying the tool named in the workshops include group management decisions, conversation-starting across and within departments, and for adding

transparency and value alignment throughout value chains – which may potentially help address some of the related barriers of transitioning to a circular economy.

5.7. CONCLUDING REMARKS

In our research, we combined theory from the fields of circular economy, transition management, industrial ecology, and decision-making to form a framework for decision-making towards a circular economy. By arguing for a new decision-making paradigm and offering an operational tool for navigating this logic in policy, practice, and society, we aimed to narrow the gap between scientific literature and practice through the creation and design of the CDMT framework. The guiding CDMT scheme built around the CDM logic was developed to improve upon existing circularity frameworks like the waste hierarchy and R-imperatives by directing decision-makers towards preferred circular initiatives, incorporating considerations such as diffusion and scaling potential, and emphasizing monitoring and evaluation of the impact of the selected initiative after a period of its implementation. The CDMT was intended to help actors select between circular innovations or proposals through a hierarchical process addressing highest-quality circularity and diffusion potential, while allowing for autonomy and flexibility in the decision-making. Through a series of focus group workshops, we enriched the first version of the tool and validated its internal logics and design aesthetic by testing it with stakeholders in various geopolitical contexts.

From the results of our exploratory study, we see the CDMT as a conceptual and operational contribution to the current scientific debate in the governance of transitioning to circular economy, and it may add to practice by offering an improved mapping of decisions and collaborative orientation in decision-making involving multiple actors or organizations. It is clear that there is a diversity of pathways for transitioning from a linear to a circular economy, and there are internal and external barriers to the transition to an economy where circular systems are the norm. In its current form, the CDMT may already help lessen the gap between science and policy by providing orientation during decisions concerning circularity, communicating a hierarchy of preferable contributions in varying impact levels to CE, drawing attention to dilemmas and uncertainties in circular decision-making, incorporating considerations of diffusion or acceleration potential, and stimulating self-reflection and debate across sectors and societal domains. In conclusion, we believe this exploratory study has filled its purpose of developing and testing a new CDM logic and related framework that add to science and practice, and we recommend that future versions of the CDMT be developed to highlight other dimensions of sustainability and sector-specific constructs, building on our original work.

5.8. APPENDIX: CDMT FIGURE ASSUMPTIONS

- By "scaling", we refer to human, material, and financial resources/capacity to scale (economies of scales, limits to growth, etc.)
- Energy requirements are implicitly but not explicitly weighed
- There is not a huge trade-off with energy use, chemicals, or other environmentally harmful manifestations of burden shifting
- The social dimension of sustainable development is not integrated (e.g., implications for labor force)
- All other components/factors remain reasonably constant (e.g., enormous transportation demands are not needed to receive the new material substituted)
- Recycling and material processing cause material and energy losses
- Distinction of technical versus biological cycles is not central
- Questions of material purity and absence of toxicity are not explicitly addressed
- Industry-specific critical sustainability challenges or material resource shortages should be developed in future industry-specific research

5.9. REFERENCES

Andersson, C., Törnberg, A., & Törnberg, P. (2014). Societal systems–complex or worse?. *Futures*, *63*, 145-157.

Antikainen, M., & Valkokari, K. (2016). A framework for sustainable circular business model innovation. *Technology Innovation Management Review*, *6*(7).

Antikainen, M., Uusitalo, T., & Kivikytö-Reponen, P. (2018). Digitalisation as an enabler of circular economy. *Procedia CIRP*, *73*, 45-49.

Avelino, F., & Grin, J. (2017). Beyond deconstruction. a reconstructive perspective on sustainability transition governance. *Environmental Innovation and Societal Transitions*, *22*, 15-25.

Ayres, R. U., & Ayres, L. (Eds.). (2002). *A handbook of industrial ecology*. Edward Elgar Publishing.

Baker, K. R., & Trietsch, D. (2013). *Principles of sequencing and scheduling*. John Wiley & Sons.

Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., & Truffer, B. (2015). Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. *Environmental Innovation and Societal Transitions*, *16*, 51-64.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research policy*, *37*(3), 407-429.

Bizcocho, N., & Llatas, C. (2019). Inclusion of prevention scenarios in LCA of construction waste management. *The International Journal of Life Cycle Assessment*, *24*(3), 468-484.

Blomsma, F., & Brennan, G. (2017). The emergence of circular economy: a new framing around prolonging resource productivity. *Journal of Industrial Ecology*, *21*(3), 603-614.

Bocken, N. M., Bom, C. A., & Lemstra, H. (2017, October). Business-led sustainable consumption strategies: the case of HOMIE. In *18th ERSCP Conference*.

Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: an overview. *Journal of cleaner production*, *45*, 1-8.

Brown, P., Von Daniels, C., Bocken, N. M. P., & Balkenende, A. R. (2021). A process model for collaboration in circular oriented innovation. *Journal of Cleaner Production, 286*, 125499

Campbell-Johnston, K., Vermeulen, W. J., Reike, D., & Bullot, S. (2020). The circular economy and cascading: towards a framework. *Resources, Conservation & Recycling: X*, 100038.

Cleary, J. (2014). A life cycle assessment of residential waste management and prevention. *The International Journal of Life Cycle Assessment*, *19*(9), 1607-1622.

Curran, M. A. (2014). Strengths and limitations of life cycle assessment. In *Background and future prospects in life cycle assessment* (pp. 189-206). Springer, Dordrecht.

D'Amico, B., Pomponi, F., & Hart, J. (2021). Global potential for material substitution in building construction: The case of cross laminated timber. *Journal of Cleaner Production*, *279*, 123487.

de Haes, H. A. U., Heijungs, R., Suh, S., & Huppes, G. (2004). Three strategies to overcome the limitations of life-cycle assessment. *Journal of industrial ecology*, *8*(3), 19-32.

Deutz, P., & Ioppolo, G. (2015). From theory to practice: Enhancing the potential policy impact of industrial ecology. *Sustainability*, *7*(2), 2259-2273.

Dijkgraaf, E., & Vollebergh, H. R. (2004). Burn or bury? A social cost comparison of final waste disposal methods. *Ecological Economics*, *50*(3-4), 233-247.

Drost, E. A. (2011). Validity and reliability in social science research. *Education Research and perspectives*, *38*(1), 105-123.

Dyer, M., Wu, S., & Weng, M. H. (2021). Convergence of public participation, participatory design and NLP to co-develop circular economy. *Circular Economy and Sustainability*, 1-18.

Ellen MacArthur Foundation. (2021). Accessed on 23 April, 2021, from: https://www.ellenmacarthurfoundation.org/

Elzen, B., Geels, F. W., & Green, K. (Eds.). (2004). *System innovation and the transition to sustainability: theory, evidence and policy*. Edward Elgar Publishing.

Finnveden, G. (2000). On the limitations of life cycle assessment and environmental systems analysis tools in general. *The International Journal of Life Cycle Assessment*, *5*(4), 229-238.

Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., ... & Suh, S. (2009). Recent developments in life cycle assessment. *Journal of environmental management*, *91*(1), 1-21.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), 1257-1274.

Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research policy*, *39*(4), 495-510.

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

Gentil, E. C., Gallo, D., & Christensen, T. H. (2011). Environmental evaluation of municipal waste prevention. *Waste management*, *31*(12), 2371-2379.

Gharfalkar, M., Court, R., Campbell, C., Ali, Z., & Hillier, G. (2015). Analysis of waste hierarchy in the European waste directive 2008/98/EC. *Waste management*, *39*, 305-313.

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.

Glasson, J., & Therivel, R. (2013). *Introduction to environmental impact assessment*. Routledge.

Greer, R., von Wirth, T., & Loorbach, D. (2020). The diffusion of circular services: Transforming the Dutch catering sector. *Journal of Cleaner Production*, *267*, 121906.

Greer, R., von Wirth, T., & Loorbach, D. (2021). The Waste-Resource Paradox: Practical dilemmas and societal implications in the transition to a circular economy. *Journal of Cleaner Production*, 126831.

Groeneveld, J., Müller, B., Buchmann, C. M., Dressler, G., Guo, C., Hase, N., ... & Schwarz, N. (2017). Theoretical foundations of human decision-making in agent-based land use models–A review. *Environmental modelling & software*, *87*, 39-48.

Guba, E. G., & Lincoln, Y. S. (1982). Epistemological and methodological bases of naturalistic inquiry. *Ectj*, *30*(4), 233-252.

Henry, M., Bauwens, T., Hekkert, M., & Kirchherr, J. (2020). A typology of circular start-ups: An Analysis of 128 circular business models. *Journal of Cleaner Production*, *245*, 118528.

Hill, J. (2016). Circular Economy and the Policy Landscape in the UK. In *Taking stock of industrial ecology* (pp. 265-274). Springer, Cham.

Hina, M., Chauhan, C., Kaur, P., Kraus, S., & Dhir, A. (2022). Drivers and barriers of circular economy business models: Where we are now, and where we are heading. *Journal of Cleaner Production*, *333*, 130049.

Holtz, G., Alkemade, F., De Haan, F., Köhler, J., Trutnevyte, E., Luthe, T., ... & Ruutu, S. (2015). Prospects of modelling societal transitions: Position paper of an emerging community. *Environmental Innovation and Societal Transitions*, *17*, 41-58.

Huang, I. B., Keisler, J., & Linkov, I. (2011). Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends. *Science of the total environment*, *409*(19), 3578-3594.

Hultman, J., & Corvellec, H. (2012). The European waste hierarchy: From the sociomateriality of waste to a politics of consumption. *Environment and Planning A*, *44*(10), 2413-2427.

IAIA (2009). *What is impact assessment?* Fargo, ND: IAIA.

Kalbar, P. P., Karmakar, S., & Asolekar, S. R. (2012). Selection of an appropriate wastewater treatment technology: A scenario-based multiple-attribute decision-making approach. *Journal of environmental management*, *113*, 158-169.

Kalbar, P. P., Karmakar, S., & Asolekar, S. R. (2016). Life cycle-based decision support tool for selection of wastewater treatment alternatives. *Journal of Cleaner Production*, *117*, 64-72.

Kemp, R., & Loorbach, D. (2006). Transition management: A reflexive governance approach. *Reflexive Governance for Sustainable Development, Cheltenham, UK and Northampton, MA, USA: Edward Elgar*, 103-30.

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technology analysis & strategic management*, *10*(2), 175-198.

Krueger, R. A. (2014). *Focus groups: A practical guide for applied research*. Sage publications.

Lewandowski, M. (2016). Designing the business models for circular economy—Towards the conceptual framework. *Sustainability*, *8*(1), 43.

Loorbach, D. (2007). Transition management. *New mode of governance for sustainable development. Utrecht: International Books*.

Loorbach, D. (2010). Transition management for sustainable development: a prescriptive, complexity-based governance framework. *Governance*, *23*(1), 161-183.

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.

Loorbach, D., Wittmayer, J., Avelino, F., von Wirth, T., & Frantzeskaki, N. (2020). Transformative innovation and translocal diffusion. *Environmental Innovation and Societal Transitions*, *35*, 251-260.

Mativenga, P. T., Agwa-Ejon, J., Mbohwa, C., & Shuaib, N. A. (2017). Circular economy ownership models: a view from South Africa industry. *Procedia Manufacturing*, *8*, 284-291.

Maykut, P., & Morehouse, R. (2002). *Beginning qualitative research: A philosophical and practical guide*. Routledge.

McDowall, W., & Geels, F. W. (2017). Ten challenges for computer models in transitions research: Commentary on Holtz et al. *Environmental Innovation and Societal Transitions*, *22*, 41-49.

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. *Journal of business ethics*, *140*(3), 369-380.

PACE - Platform for Accelerating the Circular Economy (2021). *The Circularity Gap Report*. Circle Economy.

Parker, A., & Tritter, J. (2006). Focus group method and methodology: current practice and recent debate. *International Journal of Research & Method in Education*, *29*(1), 23-37.

PBL - *Planbureau voor de Leefomgeving* (Netherlands Environmental Assessment Agency) (2017). Integrale Circulaire Economie Rapportage 2017.

PBL - *Planbureau voor de Leefomgeving* (Netherlands Environmental Assessment Agency) (2021). Integrale Circulaire Economie Rapportage 2021.

Pires, A., & Martinho, G. (2019). Waste hierarchy index for circular economy in waste management. *Waste Management*, *95*, 298-305.

Powell, R. A., & Single, H. M. (1996). Focus groups. *International journal for quality in health care*, *8*(5), 499-504.

Priyam, A., Abhijeeta, G. R., Rathee, A., & Srivastava, S. (2013). Comparative analysis of decision tree classification algorithms. *International Journal of current engineering and technology*, *3*(2), 334-337.

Quinlan, J. R. (1996). Learning decision tree classifiers. *ACM Computing Surveys (CSUR)*, *28*(1), 71-72.

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

Rijksoverheid (2021). *Nederland Circulair in 2050.* Accessed on 25 March, 2021, from: https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050

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

Rodseth, C., Notten, P., & Von Blottnitz, H. (2020). A revised approach for estimating informally disposed domestic waste in rural versus urban South Africa and implications for waste management. *South African Journal of Science*, *116*(1-2), 1-6.

Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.

Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. *Journal of industrial ecology*, *13*(2), 184-196.

Rotmans, J., Kemp, R., & Van Asselt, M. (2001). More evolution than revolution: transition management in public policy. *foresight*.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology analysis & strategic management*, *20*(5), 537-554.

Scott, J. C. (2008). Seeing like a state. In *Seeing Like a State*. yale university Press.

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research policy*, *41*(6), 1025-1036.

Smith, A., Voß, J. P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research policy*, *39*(4), 435-448.

Smith, H. R. (1979). A simulator study of the interaction of pilot workload with errors, vigilance, and decisions.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of business research*, *104*, 333-339.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223).

Thomas, V. M. (2003). Demand and dematerialization impacts of second-hand markets: Reuse or more use?. *Journal of Industrial Ecology*, *7*(2), 65-78.

Towa, E., Zeller, V., & Achten, W. M. (2021). Assessing the circularity of regions: Stakes of trade of waste for treatment. *Journal of Industrial Ecology*.

van Ewijk, S., & Stegemann, J. A. (2016). Limitations of the waste hierarchy for achieving absolute reductions in material throughput. *Journal of Cleaner Production*, *132*, 122-128.

Viaggi, D., & Zavalloni, M. (2021). Bioeconomy and Circular Economy: Implications for Economic Evaluation in the Post-COVID Era. *Circular Economy and Sustainability*, 1-13.

von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229-257.

Wieczorek, A. J., & Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. *Science and public policy*, *39*(1), 74-87.

Wittmayer, J. M., & Schäpke, N. (2014). Action, research and participation: roles of researchers in sustainability transitions. *Sustainability science*, *9*(4), 483-496.

Zink, T., & Geyer, R. (2017). Circular economy rebound. *Journal of Industrial Ecology*, *21*(3), 593-602.

Zolfagharian, M., Walrave, B., Raven, R., & Romme, A. G. L. (2019). Studying transitions: Past, present, and future. *Research Policy*, *48*(9), 103788.

6

TOWARDS CIRCULAR ECONOMY IN THE FRENCH WINE SECTOR: APPLYING THE CIRCULAR DECISION-MAKING TREE

Given the earth's finite set of resources and unwavering resource consumption trends, many sectors in various contexts are experiencing increasing pressures on biodiversity and resource use from society changing, causing increasingly problematic developments. In response to this increasing societal unsustainability, the concept of a circular economy has emerged as one widely supported strategy for reducing material consumption and waste in policy, research, and practice. Not immune to these issues – and, in some ways, especially related for their impact on and acute vulnerability to climate change effects – is the practice of viticulture and winemaking. It is still overlooked how we as a society can best strategize within complex and persistent environmental sustainability issues in this sector, given that many material-reducing practices in the wine sector focus on end-of-life solutions. In this exploratory study, we present an illustrative application of a conceptual and potentially practical framework for circular decision-making in the wine sector. Because of France's dominance in the global wine market, yet scarce signs of transformative practices over linear economy optimizations, we selected this country as our geographical scope. In this paper, we investigate the potential usefulness of the circular decision-making framework through an illustrative application in this paper. In our exploratory study on this tool – the Circular Decision-Making Tree (CDMT) –, we reflect on possible sector-specific barriers to CE and potential facilitators for improved circular innovation implementation in the French wine sector in our analysis. We conclude with a summary and final thoughts on the limitations and implications of our findings, as well as recommendations for future research.

Keywords: Circular economy, sustainability transitions, transformative practices, circular decision-making, sector-specific barriers, Waste-Resource Paradox

This paper is in its final editing stages and will be submitted for publication to an academic journal in due time.

6.1. INTRODUCTION

6.1.1. Persistent sustainability problems in winemaking

Winemaking and viticulture are practices that date back millennia (Winkler, 1974; Aleixandre et al., 2016; Wilson, 1998). Yet in recent years, the wine sector is facing increasing pressures to change these practices due to the accelerated, human-made climate change effects and biodiversity losses. Wine grapes are crops highly sensitive to fluctuations in temperature and water (Martínez-Lüscher, et al., 2016; Venios et al., 2020; van Leeuwen et al., 2017), making them also one of the best markers of climate change and leaving them as one of the most vulnerable to its effects. On a micro level, these fluctuations can result in a variation of the acidity and sugar content in grapes produced (van Leeuwen & Darriet, 2016; de Orduna, 2010; Schulz, 2016), which can affect the flavor profile of an entire vintage and its market acceptance and success. On a macro level, climate change effects could cause substantial changes in entire wine *regions*, shifting them north as earth warms and threatening regions' economies that are based principally on their reputations for, and their production of, high-quality wines for centuries (Mozell & Thach, 2014; Ashenfelter & Storchmann, 2016). Furthermore, changes in temperature and water affecting grape chemistry may change viable growth varieties in their traditional regions, and rising sea levels will cause a loss of vineyard acreage (ibid).

Not only is the wine sector facing external pressures from climate change effects, there are also increasing policy pressures to change to more sustainable practices, particularly in the European Union (EU). For example, the updated Waste Framework Directive (2008/98/EC) requires member states to establish waste prevention programs which encourage (among others) the manufacture and design of resource-efficient, durable, repairable, reusable, and upgradable products; ensuring the conservation of critical raw materials; and reducing food waste (European Union, 2008). In light of this and the European Green Deal released – aiming to transform the EU into a modern, resource-efficient and competitive economy, with no net emissions of greenhouse gases by 2050, economic growth decoupled from resource use, and no person and no place left behind –, there is increasing urgency in all sectors to adopt more sustainable practices (European Commission, 2021). EU legislation must be transposed to national policy in all member states, so it thereby also directly affects the wine sector and the dominant linear practices in European wine-producing regions.

6.1.2. Circular economy

Pressure from recent policy trends and climate change effects has already led to attempts in the wine sector towards sustainability, including regional programs and

national goal setting. Unfortunately, however, "some awareness-raising measures are established in Directives 2018/851 and 2019/904, but they are rather limited as they focus on reducing littering rather than challenging overconsumption and materialism" (Friant et al., 2021, p. 346). Both in the wine sector and in society more broadly, increasing amounts of waste produced are exceeding the earth's capacity for regeneration and natural resilience (Steffen et al., 2015). The latest Eurostat (2020) study indicates the global annual waste generation is also projected to increase by 70% by 2050 (World Bank, 2018). It is therefore widely posited that we are in desperate need of a substantial reduction of these wastes, and one increasingly popular proposition to address these systemic waste inefficiencies is by envisioning a circular economy (CE) future. The CE concept is defined by its aim to gradually decouple economic activity from the extraction and consumption of finite resources and to design waste out of the systems, and it has become central in academia, policy, and industry (Korhonen et al., 2018). In particular, this zero-waste systems approach is based principally on extracting the least possible virgin materials from the earth and, secondly, on the slowing and closing of resource loops (Kirchherr et al., 2017; Ellen MacArthur Foundation, 2021).

This shift away from the current dominating "take-make-waste" paradigm of the linear economic models dominant in winemaking to a circular economic system of operation is one transformative answer to its persistent sustainability problems, but it requires fundamental shifts in institutions, traditions, practices, and structures: i.e., a transition in the wine sector.

6.1.3. Sustainability transitions theory

Research on such transitions to sustainability refers to the fundamental societal shifts in cultures, structures, and practices that take place in a complex, non-linear fashion over decades or generations related to sustainability (Markard et al., 2012; Grin et al., 2010; Loorbach & Rotmans, 2010). A sustainability transition is defined as a "radical transformation towards a sustainable society, as a response to a number of persistent problems confronting contemporary modern societies" (Grin et al., 2010, p. 1). The wider agri-food system has already been characterized in recent years by applying transition theory (Borsellino et al., 2020; Audet et al., 2017; Vermunt et al., 2020; Hebinck et al., 2021); in this paper, we also see it fit to take a transition perspective as our conceptual framing to tackle this complex societal puzzle of how to increase transformative sustainable practices in the wine sector.

Within a transition, there are three key levels of a societal system: the landscape, the regime, and the niche. The "landscape" is the context in which society operates, an external structure consisting of deep structural trends (Geels, 2002). The "regime"

refers to the dominant incumbent cultures, structures, and practices. Regimes are often path-dependent and locked into unsustainable development trajectories, whereby current decisions are influenced by inertia of previous decisions and are made based on past contextual factors (Kallis & Norgaard, 2010; Sartorius, 2006; Tukker & Butter, 2007; Seyfang et al., 2012). In contrast, the "niche" represents the counterculture, often radical initiatives or actors that begin to form and that may constitute a catalyst for a future transition (Geels & Schot, 2007; Schot & Geels, 2008). A transition co-evolves between a dynamic interplay from these three levels, as one of the early models of transition theory, the Multi-Level Perspective, suggests (Geels, 2002; Geels, 2014; Smith et al., 2010).

Within transitions science, there are academic discussions about diffusion of sustainable innovations, one primary facet of which is upscaling. Rogers (2003)'s S-curve is considered to be one of the founding conceptualizations of innovation diffusion; in sustainability transitions, we adopt this idea of diffusion and examine the spreading or strengthening of sustainable innovations through various mechanisms of growth (Loorbach et al., 2020). One type of diffusion is referred to in sustainability discussions as scaling; by this, we mean the internal development and growth of niche experiments (Liedte et al., 2015). There are various types of scaling up, including: "spatial scaling (geographical growth), content scaling (extending across domains and practices), actor scaling (extending towards different partnerships and actors involved), and resource scaling (expansion of funding)" (von Wirth et al., 2019, p. 233). These are important considerations in the potential impact of an innovation, which we will revisit later in our analysis in this paper.

6.1.4. Circular economy in the wine sector

In contrast to markets such as energy (renewables and cooperatives) and mobility (electrification and shared or healthy mobility), the wine sector so far lacks such alternatively emerging transition pathways. While some strategies such as organic and biodynamic winegrowing have been developed (and have experienced relative success with producers and consumers alike), these do not address many other impacts caused by winemaking, such as increasing resource scarcity and low system resilience to economic and environmental events (McWilliam & Wesener, 2021; Delmas & Lessem, 2017; Villanueva-Rey et al., 2014). Furthermore, these certifications for organic or biodynamic wine fail to adequately address materials involved in winemaking outside of viticultural processes (related to the grape harvest). Crucially, these other stages should not be overlooked: they create demand for large quantities of glass, cardboard and plastic packaging materials, and for pallets and fuel for transportation involved in the rest of the winemaking process (Stuckrath Alvarado, 2020). Thus, current sustainability

policies, innovations, and interventions in the wine sector seem to be at least partially missing the mark.

Similarly, some researchers have already examined energy demands and potential (Croonenbroeck & Lowitzsch, 2019; Galitsky et al., 2005; Dóci et al., 2015; Garcia-Casarejos et al., 2018), but much less literature examines sustainable resource and material use in winemaking. Even less literature exists on CE in the wine sector specifically. In the limited studies that do address circular economy in wine, it seems that there is a lack of congruency with CE foundational principles. In the systematic literature review by Berardi and Dias (2019), 33 out of 41 manuscripts address CE as related to waste, while *none* deal specifically with transformative innovations or improving over optimization of linear economy. "Optimization" refers to incremental improvements largely reinforcing the current regime (Loorbach et al., 2017). The large majority of literature on sustainable viticulture and winemaking addresses *adapting* to environmental fluctuations (Ollat et al., 2016; Lereboullet et al., 2013; Santos et al., 2020; Santillán et al., 2020; van Leeuwen et al., 2019); what appears to be lacking both in literature and policy is addressing the deeper structures of the wine life cycle, as well as a way to navigate the pathways collectively contributing towards the goal for a more sustainable future, set at various levels of governance related to this field.

In the transition to a circular economy, it can be anticipated that the lines between a waste and a resource blur, described in the literature as the Waste-Resource Paradox (WRP) (Greer et al., 2021). A result of the WRP is that this can commonly lead to optimization of linear models, rather than shifting to circular models. Relatedly, while there is some mentioning of circularity or circular economy in sustainability plans for regional winemaking (Comité Champagne, 2015), it is often being used in a sense incongruent with the literature and the core principles of CE. Most efforts related to circularity in the French wine sector attempt to make use of a waste product as a resource in another way (Renaud, 2019), including the valorization of marc, pomace, and distilled wines, or the potential for use of grape-seed oils for pharmaceutical, cosmetic, and food applications (Alfonso et al., 2018). In this paper, we seek to address this incongruence through the application of an analytical tool for circularity, and we explore barriers that may impede the transition and potential ways to address these barriers.

6.1.5. The French wine sector

France is well known as one of the world's largest wine markets, in 2019 constituting 25% of the total global wine production (Eurostat, 2020). Because it is one of the most dominant wine producers and markets in the world, we take the French wine

sector as the boundary for our research context. Despite some small circular pushes and a broader incremental move towards efficiency and sustainability, disruptive and transformative innovations in the French wine sector remain scarce. This may be because circularity in the French wine sector is more commonly used to address organic waste from viticulture practices, and different, separate indicators are applied to packaging and glass (Bois et al., 2021; Comité Champagne, 2015; Chatel et al., 2021).

The French wine sector does have sustainability-related goals, such as lessening the sector's footprint and lowering negative environmental impacts. While progress is slow, some sustainability considerations have begun to be embedded and measured in the last years. An important press release from the region of Champagne (Comité Champagne, 2015) describes its true and ideal engagement and responsibilities related to current environmental concerns. It states a goal of 75% carbon emission reductions by 2050 – indicating that there is a desire and need for a sustainability transition to occur. Certain regulations and certification schemes (ISO 14001, EMAS, VinNatur, Fairtrade, Demeter's Biodynamic Certification, etc.), organizations (OIV.int, vitisplanet.org, IFV, National Federation Terra Vitis), and projects (Life-ADVICLIM, ECOWINERY, biodivine.eu) related to sustainability in the French wine sector have emerged; yet, we currently observe most activities in this context to be consistent with optimization of the linear regime.

Similar to the results of our more general literature review, there was little existing research to be found on CE as related to viticulture and winemaking in France. Some circular-adjacent literature in other contexts such as the Italian the Spanish wine sectors exists, like Valero et al. (2019)'s sustainable wine scoring system. In the French context, environmental factors controlling wine quality in Saint-Emilion have been identified (Fayolle et al., 2019), but the study lacks a proposal of future pathways for a strategic approach on how to move forward. Substantial attention has been given to organic wine production in France (also in the literature), with a national production of over 100 million organic bottles of wine (16.4% of the world market) in 2017 (Baiano, 2021) – but no structural change has taken place yet.

6.1.6. The transition to CE in the literature and in practice

The European Environmental Bureau (2021) has called for circular targets and has highlighted their urgency; yet, most EU Member States have seen limited CE implementation so far, missing their recycling targets while waste generally continues to rise (McDowall et al., 2017; Stahel, 2014). Scholars have attributed the limited progress in CE implementation to a variety of CE barriers, with the topic rising in interest in academic studies in recent years (see, for example, de Jesus & Mendonça, 2018;

Grafström & Aasma, 2021; Greer et al., 2020; Ranta et al., 2018; Ritzén & Sandström, 2017). Despite there being extensive research on general barriers to CE, Kirchherr et al. (2018) – who conducted a review of barriers to CE in the EU – conclude their work by identifying a need to "explore CE barriers in specific sectors or business models" (Kirchherr et al., 2018, p. 271). We also recognize this gap in the literature on explorations of sector-specific barriers to a CE in the EU, and we address this with one illustration in our paper.

Further, Hina et al. (2022) analyzed 126 studies on barriers to circular economy business models discussed in the literature to "identify the thematic research areas, recognize the research gaps and present future research agendas" (p. 1). The results of their comprehensive review indicated that there is still a research gap around the social, cultural, and environmental barriers in implementing circular economy business models. They suggested that researchers address the question surrounding the strategies and initiatives firms can undertake to address the social, cultural, and environmental issues involved in circular economy business model implementation (ibid). We keep this inquiry in mind during our study, and we have aimed to add knowledge to this gap through our illustration of the CDMT – though not the primary focus of our work.

Additionally, Kirchherr et al. (2018)'s research findings suggest that "an intervention strategy is needed that does not focus on research and development (R&D) for CE any longer" (Kirchherr et al., 2018, p. 265). While the circular decision tree tool comes from and is built on research foundations, its pragmatic design aims to be implementable by practitioners outside of research – its purpose then is to be an alternative in practice to prevalent case studies and other interventions that have an exclusive research orientation. Accordingly, we address this call to reflect on sector-specific barriers to CE, as well as the call to explore a non-R&D intervention strategy in circular economy, in our paper: through an illustrative application of circular decision tree framework to explore CE barriers in the French wine sector. Further, we reflect on some sector-specific facilitators for CE during the exploration.

Rather than implementing small and incremental innovations towards sustainability (i.e., optimizing), a better pathway to sustainability can be to jumpstart the transition in this sector by avoiding these optimizations of linear practices and immediately implementing radical innovations that change or challenge the underlying linear paradigm as a whole. Since there are insufficient policy or financial incentives to change from the current linear paradigm to a new system of operation of a circular French wine sector – yet a high vulnerability associated with not doing so – and current initiatives are not translating into a transition, we propose applying circular economy principles

and practices to the French wine sector through the use of an existing framework described in the following section.

In our research, we set out to explore the utility of a circular decision-making tool – one non-R&D intervention strategy in circular economy –, as well as identify sector-specific barriers to CE in French wine, and further, to reflect on potential facilitators (to address some of these barriers) through the illustrative application of a circular decision-making framework. Accordingly, we have formulated the following research questions:

- *What are barriers to the transition to CE in the French wine sector, and what are potential facilitators of CE to address these?*
- *How might the circular decision-making framework be applied in the French wine sector to navigate this transition?*

6.2. METHODOLOGICAL APPROACH

Consistent with the research's aim to explore an intervention strategy in circular economy and potential barriers to CE in the French wine sector, we take a qualitative exploratory methodological research approach in our paper. "Exploratory research, as the name implies, intends merely to explore the research questions and does not intend to offer final and conclusive solutions to existing problems... [It] is not intended to provide conclusive evidence, but helps us to have a better understanding of the problem" (Mbaka & Isiramen, 2021, p. 29; Stebbens, 2001). Accordingly, this analysis is not intended to be a comprehensive list of barriers and facilitators of CE in the French wine sector, or conclusive evidence that the application of our selected circular decision-making framework fits unquestionably in empirical settings – but rather, a set of insights on how we might go about the transition to a circular wine sector based on lessons learned from the application of the circular decision-making (CDM) logic.

To structure the research in this paper, we followed the framework of exploratory research by Jaeger and Halliday (1998), first addressing the novelty of the situation and elucidating its importance, and finally discussing the inferences gained from the data analysis. Given the exploratory nature of transition research and this paper specifically, we drew on a pragmatic methodological approach, which involves a research design based on what fits a specific situation the best in finding answers to the research inquiries, which enables innovative ways to address research problems (Kelly & Codeiro, 2020). Over the last decades, qualitative research methods have been recognized as a valuable tool in sustainability transitions research (Markard et al., 2012). Thus, we selected a qualitative methodology because we have taken a transition lens to frame

our study, and qualitative methods are generally recognized to be most appropriate for a descriptive study of this nature.

Data collection for this paper was undertaken throughout 2020 and 2021. Our methods involved a review of extant literature and EU policy documents on sustainability and circularity, then paired with our application of the CDMT analysis. The review included scientific studies (both French and English), EU policy documents and French national statistics reports (e.g., the EU Green Deal, OIV [International Organization for Wine] statistics report), and French regional press releases on goal setting in sustainability/ sustainability assessments and plans for the region (e.g., Champagne). Our data sources were acquired through an academic database and web search of sources with the keywords "France, French" and "wine, viticulture, vitiviniculture, oenology", in combination with the following keywords: "circular, sustainability, waste, innovation, material and energy reduction, efficiency" (individually paired with each former key term). We included a Google search as a valid data source to find and analyze regional policy and roadmap documents within France, as well as because much of academic CE literature is connected to or shaped by practitioner writings (Blomsma & Brennan, 2017; Kirchher et al., 2018, Schut et al., 2016). We reviewed these sources to develop a fundamental understanding of the current state of circularity (or lack thereof) in the French wine sector.

We then applied the Circular Decision-Making Tree (CDMT) (Greer et al., *under review*) to address the lack of high-quality circularity innovation implementations understood as a result of the literature review on sustainability and circularity in the French wine sector. The CDMT is a tool that was designed to shed light on various options and allow the user to map alternatives and identify an array of alternatives during circular decision-making. By narrowing down options to identify those of highest-quality circularity and improving strategy, uncertainties may be reduced at an early stage, and barriers and facilitators may emerge during reflections on the use of the tool. An exploration of the usability of the CDMT has, at the time of this writing, not yet been adequately explored in the literature. Thus, we analyzed the circularity in the French wine sector from this CDMT perspective, illustrating how the framework might be applied in a particular sector, and we reflected on these explorations.

6.3. APPLICATION OF THE CDMT TO CE IN THE FRENCH WINE SECTOR

Thus far, we have described the state of the transition to CE in the French wine sector, the gaps in literature and practice on this topic, and our methodological approach. In this section, we explore an example of one potential intervention that may be useful for reprioritizing circularity options through a new type of circular decision-making logic. To do this, we build on the logic of the CDMT by Greer et al. (*under review*). For a reproduction of the illustrated tool, see Figure 8.

Specifically, in this section, we apply the CDMT to reflect on higher-impact innovations through the first and "Operational" column of the heuristic, examine questions of the diffusion potential and pathways of said innovations through the second and "Strategic" column of the CDMT, and discuss the (lack of) relevant indicators and implications of an innovation's implementation in the French wine sector context through the third and last "Reflexive" column of the tool.

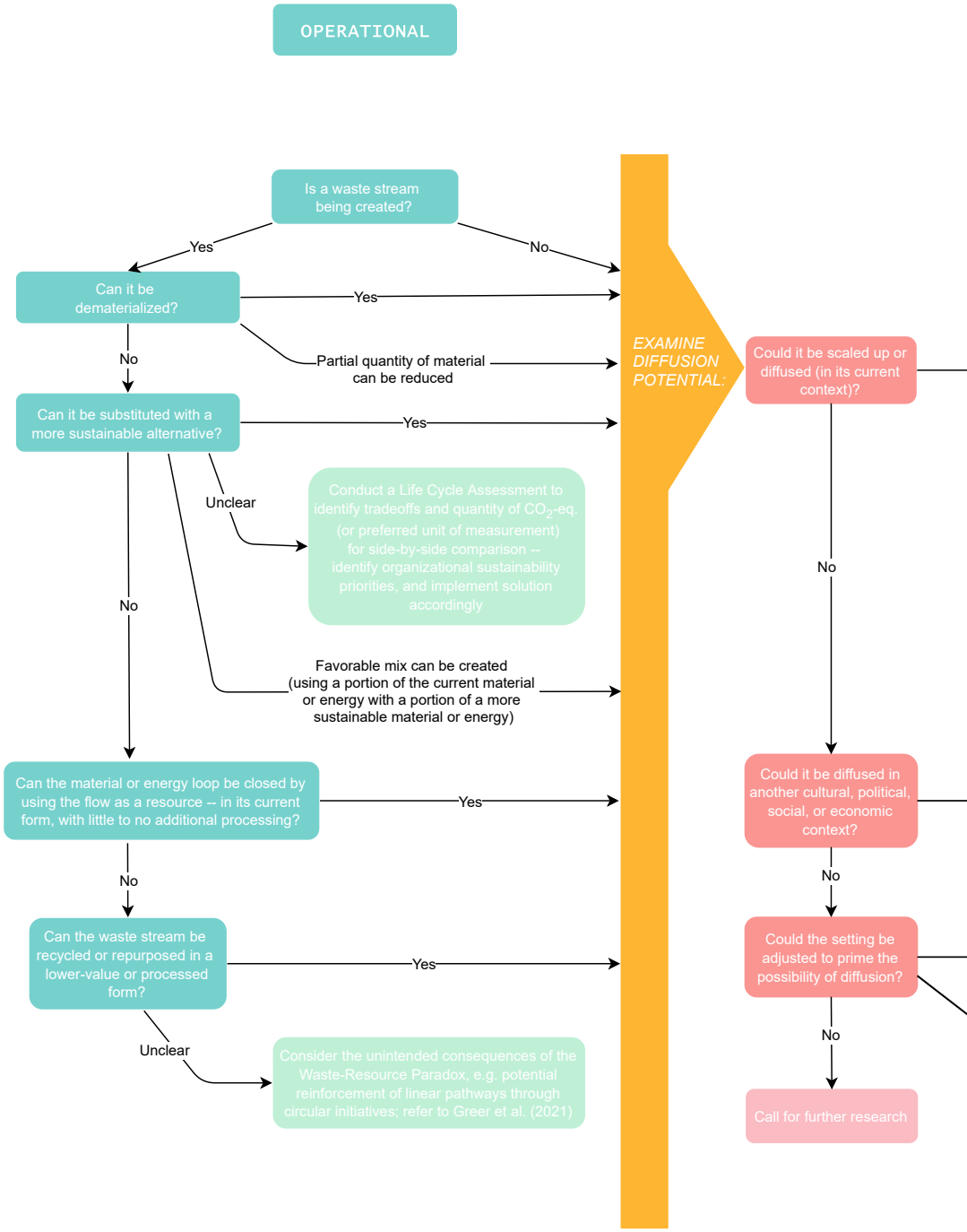
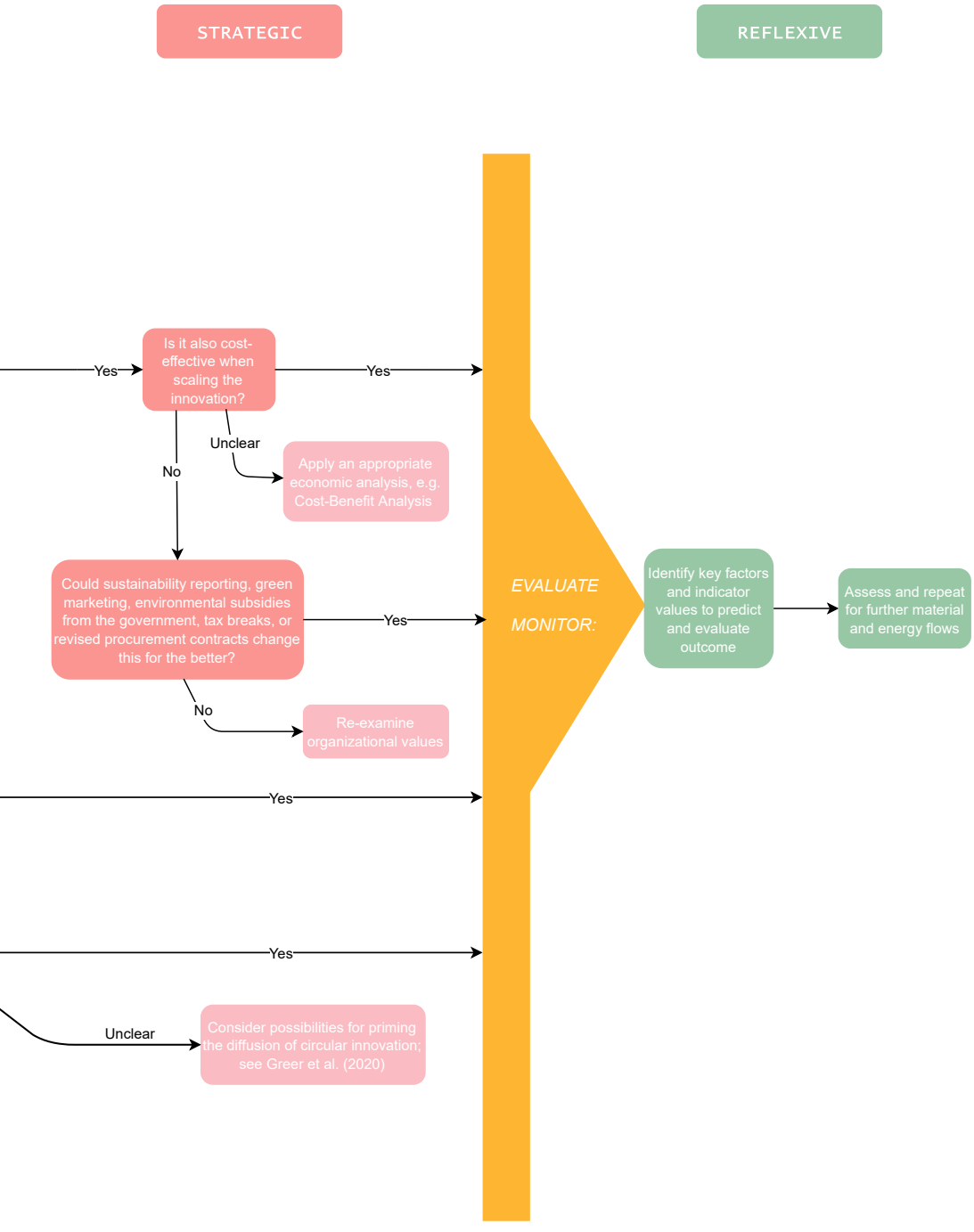


Figure 8: The Circular Decision-Making Tree (CDMT) (taken from Greer et al., *under review*)


STRATEGIC
REFLEXIVE
Yes
Is it also cost-effective when scaling the innovation?
Yes
Unclear
Apply an appropriate economic analysis, e.g. Cost-Benefit Analysis
No
Could sustainability reporting, green marketing, environmental subsidies from the government, tax breaks, or revised procurement contracts change this for the better?
Yes
No
Re-examine organizational values
Yes
Yes
Unclear
Consider possibilities for priming the diffusion of circular innovation; see Greer et al. (2020)
EVALUATE
MONITOR:
Identify key factors and indicator values to predict and evaluate outcome
Assess and repeat for further material and energy flows

6.3.1. Innovation reprioritization – "Operational" column of CDMT

The CDMT can be used as a reference to avoid or reduce the negative effects associated with the pitfalls of the WRP we see manifesting in the French wine sector. Following the CDMT logics, we first turn to the strategy of dematerialization, examining all the materials that go into the production of a bottle of wine. Since dematerializing the wine itself is not an option, this could alternatively mean: dematerializing glass bottles by reducing the total weight of the bottle; dematerializing the glass by avoiding future glass production through total reuse of an existing bottle; or dematerializing the plastic and cardboard packaging and wooden pallets used in shipping. The heat and water used for sterilization of bottles treated with steam saves a staggering amount of water and energy, in contrast with recycling: this scenario used nearly 600x the amount of water for the recycling as for the reuse and also nearly 600x the amount of heat to melt the glass for recycling versus to sterilize the reused glass (Landi et al., 2019). Benefits can be also obtained by implementing a reuse scenario for the packaging, e.g., through reusable rigid plastic boxes for bottles in wine distribution and in the collection of end-of-life bottles (ibid).

When dematerialization is not an option, we look at material substitution: two options for substituting a more sustainable material in this process include substituting recycled glass for virgin glass and substituting lighter bottling materials for glass. The recycled glass scenario is already a step less advantageous than (partial) dematerialization, in part because new bottles can only be formed with a maximum of 57.5% recycled glass for quality reasons (Landi et al., 2019). Even if the glass recycling rates are currently very high in most of the developed countries (up to 80%), and this scenario is considered a best practice in the context of waste management, since it leads to savings of virgin materials, it requires high quantities of energy for the cullet processing and melting.

These propositions are also supported by the 51-study synthesis of LCAs and beverage packaging by Sazdovski et al. (2021), who pool assessments of the highest-quality circular possibilities in the product–component–material circular hierarchy and make concluding recommendations to respectively: reduce bottle weight, reduce packaging, incorporate eco-design, and lastly to incorporate more recycled content into the glass and packaging. In one practical example, Cooper (2019) has innovated wine packaging with PCR PET bottling that is 40% more spatially efficient than round glass bottles. Their flask shape stacks flush next to each other (in contrast to the current typical cylindrical shape), allowing for more wine in one shipment and thereby lessening the amount of fuel for transport needed per bottle. Using PCR PET – 87% lighter than the average glass wine bottle – also lessens the demand for fuel in transport.

Continuing in following the logics of the CDMT, we arrive at the last and least preferred option of this column – yet the most discussed and addressed in literature and practice (Sette et al., 2020; Rivera et al., 2021): to close the loop of a waste stream by finding a way to turn it into a resource. A report from Champagne (2015) showed that 17% of the region's carbon footprint is attributable to viticulture wastes and by-products. We acknowledge that a carbon footprint measurement is not the same as a circularity assessment, but it is generally highly correlated. We are thus critical about the majority of sustainability initiatives focusing only on this part of the life cycle – when addressing the remaining 83% clearly offers more space and potential for sustainability gains and lowered environmental impact.

6.3.2. Barriers and facilitators – "Strategic" column of CDMT

After identifying a higher-quality circularity practice, we reference the CDMT to examine the diffusion potential of such innovations in the French wine context. Using a similar approach in the second "Strategic" column of the CDMT, we take the innovation selected from the first "Operational" column and examine it for scaling and diffusing possibilities. This element of a circular innovation's scalability and diffusability is important because it tells us about the greater overall impact potential of said innovation – which, surprisingly, is a consideration that is lacking in many other circular frameworks. This is to say, an innovation that designs out much material input need and that would generally be considered "more circular" is unlikely to make a significant impact on virgin material extraction reduction if it cannot be scaled or diffused in its current or other contexts.

Thus, in this section we will take the example of Cooper (2019) described in the previous section, as this encompasses an example of what might be selected as the "most circular" innovation, in comparison with other alternatives described. Now that it has been selected, we are led to the yellow category arrow to "Examine diffusion potential". The following texts in bold refer to the constructs in the second column of the CDMT (see Figure 8 for reference).

Upscaling in current context. First, we are prompted to consider if this innovative bottling and packaging could be scaled up of diffused in its current context: in this case, France. In examining this step, we might consider that:

Barrier: Sense of place – a people-place bond (Raymond et al., 2021), and economies of scale – as related to this paper, capacity limits based on resource caps (Stigler, 1958), may play a role in the French wine sector. Unlike in most industries, winegrowers are inherently bound to their land, and thereby the capacities of their land. Because of

economies of scale, they may be unable to scale up this circular packaging option beyond their winery.

Facilitator: This barrier may be alleviated by facilitating the formation of clusters with other wineries, creating industrial symbioses – meaning, placed-based mutually beneficial exchanges of materials, energy, or information (Chertow, 2000), or adopting a form of sharing economy – by which we refer to activities that include "recirculation of goods, increased utilization of durable assets, exchange of services, and sharing of productive assets" (Schor, 2016, p. 2). Together, wineries could sum their outputs collectively, increasing potential for scaling up the innovation.

Barrier: Languages not shared may also serve as a barrier for the diffusion of information, research, and practices surrounding circularity in this context. A large group of research on sustainability and wine is published or presented only in French, making it less accessible to others with a different native tongue – and vice versa.

Facilitator: This may be alleviated by (lobbying for) government allocation of financial support for translating works and connecting countries. It is possible that a weaker bilateral connection with the larger group (i.e., winegrowers worldwide) slows cross-border diffusion of information, which could be addressed through this allocation.

Cost-effectiveness of scaling up or diffusing: Second, if the formation of clusters implementing sharing economy principles allows these bottling innovations to be scaled to a greater market/audience in principle, then it is important to examine the cost-effectivity of doing so – the next consideration following the CDMT logics. If it would clearly result in a cost-effective investment, the logical step is to continue with this innovation and consider taking up and implementing this new bottling system – moving forward with this innovation to the third and final "Reflexive" column.

Barrier: Yet, the cost-effectivity of such an operation may be unclear – then the logics of the CDMT recommend conducting an economic analysis that the actor or organization sees fit.

Facilitator: As a springboard, the CDMT offers the example of conducting a cost-benefit analysis, because it is designed to measure all benefits and costs in terms of a currency (e.g., dollar, euro) value (Boardman et al., 2017). This is just one idea to begin brainstorming on economic tools to apply; the expert using the CDMT may select this or whichever economic assessment they believe to be most appropriate with their expert knowledge of the sector.

New financial implications related to circular implementation: If it is clearly not cost-effective, then one may consider the next step following the logics of the CDMT: if such a circular implementation might *become* more cost-effective based on an extension of the innovation implementation, e.g., through sustainability reporting and marketing or through a new eligibility for certain external funding/resources awarded based on the incorporation of the more circular innovation.

Barrier: In the case of French wine, a barrier to this may include the EU's CE measures falling short. Caught in the WRP trap, these EU policies and measures as described in the Introduction often allow for increased recycling and linear economy optimization, rather than true transformative changes that contribute to a shifting paradigm towards a circular economy.

Facilitator: A transition to circular wine in France might better be facilitated through proper financial (dis)incentives. In the wine sector, this might include more general policies such as the implementation of pay-as-you-throw systems, fiscal incentives for food donations, deposit-refund schemes, ending fossil-fuel subsidies, and taxing virgin materials. Further, it might include the sector-specific ideas to offer loans or subsidies to invest in steam-cleaning machines to enable reuse of other bottles that are still being made from glass.

Barrier: Another financial barrier may include increased costs surrounding the procurement of more circular materials, e.g., empty glass bottles to clean and reuse, and overcoming related new logistical barriers, such the switching from virgin glass suppliers to PCR PET suppliers for the bottle materials.

Facilitator: Integrated and synergistic strategies throughout the supply chain could prove to be a facilitator for easing of financial burdens – if, for example, circular values were discussed and prioritized in advance. Touching back on the idea of the cluster of eco-wineries and sharing economy, contracts could be created between partners to ensure the fair allocation of machines, instruments, and equipment – thus dividing the material use burden between the organizations involved. Machinery such as the steam cleaners which need not always be in operation at a single winery could be one such example of an available opportunity. Similarly, more favorable prices during supplier negotiations for the PCR PET bottle supply could result from forming a cluster and offering a higher demand, as well as the ability to buy in greater bulk. More wineries involved in a joint procurement means more demand for this alternative, more circular material – which in turn means greater leverage during material procurement negotiations and potentially a more favorable price. Of course, collaboration may

increase internal complexity, but these ideas, among others, might be enough to make the circular wine innovation a viable option – thus, leading us to a theoretical affirmative answer on this step of the decision tree, bringing us to the third and final column.

Scaling up or diffusion in an alternative context: For illustrative purposes, however, suppose that in addressing the first step of this column, it was answered that the innovation could *not* be scaled up or diffused in its current context. Then, the logics would lead us to the next question: could this circular packaging/bottling be diffused in another cultural, political, social, or economic context?

Barrier: Cultural entrenchment and deep path dependencies may also be a barrier to the upscaling of unfamiliar wine bottle shapes and materials. French wine traces its history to the 6th century BC, with many regions dating their winemaking back to Roman times (McGovern et al., 2013; Ashby, 2008). The linear path dependencies in this sector have thus been reinforced for a great many of years, making it one of the chronologically longest-entrenched sectors in linear pathways.

Facilitator: Based on this, we can consider that other countries without such a long, rich tradition of wine as part of their culture might be more open to atypical bottle shapes and materials. The Netherlands is one such country, and the Dutch government has also made the goal to become fully circular by 2050 (Rijksoverheid, 2022). One might then hypothesize that a significant portion of the population and government would value circularity over tradition in the packaging of their wine, and that this might be a context in which to try out the innovation instead.

If considering these or other alternatives facilitates the process of this circular adoption, then one may move to the "Reflexive" column.

Adjusting the setting to prime the possibility of diffusion. Otherwise, if these or other alternatives facilitate the process of this circular adoption are not an option, we are prompted to consider if the setting might be adjusted to prime the possibility of diffusion in the next step of the CDMT.

Barrier: However, the setting still might not be able to be adjusted to facilitate the upscaling or diffusion of the circular innovation. This could be due to a barrier of a lack of CE research in the French wine sector described in the Introduction (on which the CDMT then recommends future research to be conducted).

Facilitator: Still, the transition to CE in this case might be facilitated by applying existing research from other contexts to the French wine sector in hopes of transferability. For example, if the answer is unclear, we may look to, among other research e.g., Greer et al. (2020) for insights on principles for priming the setting for the possibility of scaling up of circular innovations, or Landi et al. (2019) for insights into the quantitative data on best possibilities in wine bottling, whose results were indicated to be generalizable to other contexts.

6.3.2.1. Summary of drivers and facilitators discussed

By applying the CDMT as a reflection tool, we identified various potential barriers specific to the French wine sector, which we used to trigger solutions-oriented thinking – through our analysis from the second "Strategic" column of the CDMT on diffusion potential. Based on this exercise, we named eight barriers that may act as obstacles to engaging with and accelerating the desired transition: sense of place and economies of scale, language, uncertainty about or lack of cost-effectivity, shortcomings of the EU's CE policies, increased procurement costs, lock-in of linear path dependencies, lack of research, and generalization of databases (see Table 8).

Complementing the reflection around barriers to CE in the French wine sector, we identify eight potential facilitators of CE in the French wine sector that may address these barriers: forming clusters and sharing economy principles, funding translations and increasing international connectivity, conducting an appropriate economic assessment, financial (dis)incentives, integrated and synergistic partnering strategies, considering in another social, political, geographical, or economic setting, applying existing research from other contexts (replication), and improving top-down pressures and support. See Table 9 for details.

Table 8: Barriers identified from CDMT analysis of diffusion potential

CDMT construct	Barriers to CE in the French wine sector	Barrier description
Upscaling or diffusion in current context	Sense of place and economies of scale	Winegrowers and producers are bound to their land (not a mobile sector), but also have strong connection/attachment to land. Similarly, they have a finite capacity for wine production (and thereby, circular impact potential) based on their limits to size of this land and their winery.
	Language	A large group of research on sustainability and wine is published or presented only in French, making it less accessible to others, and vice versa.
Cost-effectiveness of upscaling or diffusion	Uncertainty about or lack of cost-effectivity	Most organizations will follow regulations at the most basic level possible because it has the least resistance, likely costs the least, and is simplest for integrating into current practices. The circular innovation implementation may likely come with investment costs, and these can be too uncertain or too costly.
New financial implications related to circular implementation	EU's CE measures fall short	Caught in the duality of the WRP trap, these regulations mainly increase recycling rates rather than building transformative change that would shrink, slow, localize, redistribute, and democratize resource cycles (Fitch-Roy et al., 2020; Moraga et al., 2019).
	Increased procurement costs	Another financial barrier may include increased costs surrounding the procurement of more circular materials, e.g., empty glass bottles to clean and reuse, and overcoming related new logistical barriers, such the switching from virgin glass suppliers to PCR PET suppliers for the bottle materials.
Scaling up or diffusion in an alternative context	Lock-in of linear path dependencies	French wine traces its history to the 6th century BC, with many regions dating their winemaking back to Roman times (McGovern et al., 2013; Ashby, 2008). Regulations on maintenance of quality standards can be imposed both formally by supermarkets and federal regulatory bodies, and informally from the market as a result of social and cultural expectations.
Adjusting the setting to prime the possibility of diffusion	Lack of research	As identified in the Introduction, any research on the transition to a circular economy in the wine sector, particularly in France, is scant. Cyclically, a potentially unsustainable winery/cluster may not be open to doing case study research, further entrenching the current regime and path dependencies.
Identifying key factors and indicator values (addressed in the following subsection)	Generalization of databases	This generalization of databases brings about a lack of indicators and a risk of developing misleading indicators. We see this already in some ways with the viticulture waste valorization categorized as circularity, without nuance about higher-quality circularity potential through alternative innovations.

Table 9: Potential facilitators of the CE transition

CDMT construct	Facilitators of CE in the French wine sector	Facilitator description
Upscaling or diffusion in current context	Formation of clusters, industrial symbioses, and sharing economy principles	If the necessary machinery and equipment for wine production can be shared or rotated between a group of wineries in a coalition, this constitutes an effective collective dematerialization strategy by drastically reducing the need for individual material-heavy requirements.
	Fund translations and increase international connectivity	Allocate funding to ease bilateral connections with winegrowers worldwide, e.g., through translation of research and reports, to increase cross-border diffusion of information.
Cost-effectiveness of upscaling or diffusion	Conduct an appropriate economic assessment	The CDMT offers one option: a cost-benefit analysis (CBA), because it is designed to weigh all costs and benefits, resulting in a bottom-line currency value.
New financial implications related to circular implementation	Financial (dis)incentives	Introduce state level pay-as-you-throw systems, fiscal incentives for food donations, deposit-refund schemes, ending fossil-fuel subsidies, taxing virgin materials, and offer loans or subsidies to, e.g., invest in steam-cleaning machines to enable reuse of bottles.
	Integrated and synergistic partnering strategies	Wine producer associations that reconcile the extreme fragmentation of the production and commercialization system may collaborate, creating potential for dematerialization. Jointly developing contracts can increase transparency and encourage reduction of material extraction throughout the value chain to overcome certain financial barriers, logistical barriers, and critical issues inherent to the territory and market situation in France.
Upscaling or diffusion in an alternative context	Consider in another social, political, geographical, or economic setting	In the wine sector, other countries without such a long, rich tradition of wine as part of their culture might circularity over tradition in the packaging of their wine, and that this might be a context in which to try out the innovation instead.
Adjusting the setting to prime the possibility of diffusion	Applying existing research from other contexts (replication)	Landi et al. (2019) assert that their proposed bottle reuse scenario is not dependent on the location of the wine consortium and could be replicated in other geographical contexts.
Identifying key factors and indicator values (addressed in the following subsection)	Improving top-down pressures and support	We call on (inter)national governments to implement improved or refined policies in CE to facilitate better progress in the wine transition, because if regulations allow space to only optimize, this is likely the pathway that will be taken.

These tables are not intended to be exhaustive, but a representative of a sampling of potential approaches to illustrate the application of the CDMT to a sector. Some of these are also related to key factors and indicators of sustainability in the French wine sector, which will be addressed more in depth in the next section.

Lastly, some of the facilitators described above may allow us to answer "yes" to the question regarding the setting's ability to be adjusted to create more potential for diffusing the circular bottling and packaging concept. In this case, we take the final step and yellow arrow direction to "Evaluate and Monitor", and progressing to the third and final set of the CDMT circular decision logics.

6.3.3. Evaluation and monitoring – "Reflexive" column of CDMT

Identifying key factors and indicator values. A lack of refined data collection, evaluation, and monitoring may obfuscate the material demands, environmental impact, and potential improvements in processes and products.

Barrier: The wine sector is usually not studied on a national or international level distinct from general agriculture; yet, its material and energy inputs, demands, and outputs can differ significantly from its various agricultural counterparts. For example, its indistinction from other types of agriculture was a component in our ultimately unsuccessful search for quantitative data and statistics about the French wine region. A generalization within databases can mean a lack of or risk of misleading circular economy indicators. Cyclically, a potentially unsustainable winery or cluster may not be open to participating in case study research, which in turn does not allow them to improve their practices based on the results of that hypothetical study, further entrenching the current regime and path dependencies.

This lack of clarity and distinction about what CE is and how the French wine sector can best engage with this transition indicates a lack of effective innovative governance to implement initiatives in a cumulatively transformative way. This notion is quantitatively supported by an annual material flow analysis (MFA) from Eurostat (2020) over the last 10 years, showing no significant difference in the extraction of natural resources in France – the basis of circular economy – despite some efforts towards circularity and sustainability across this time. At the time of writing, we could not find any sector-specific MFAs for viticulture or winemaking, but based on these national level figures, we are left to assume the wine sector has a similar picture. In the same vein, manifestations of the WRP in the transition zone between a linear or circular economy may result more often in dilemmas (as described in Greer et al., 2021) when incorrect or misleading

indicators are employed. For example, this can commonly lead to optimization of linear models, rather than shifting to circular models. While these efforts may be well-intentioned, the WRP indicates that they could actually lead to an environmental rebound effect and/or further reinforcement and entrenchment of linear pathways in place, counter-productive to the goal of making the sector more sustainable.

Facilitator: The EU's CE measures also fall short thus far; caught in the duality of the WRP trap, these regulations mainly increase recycling rates rather than building transformative change that would shrink, slow, localize, redistribute, and democratize resource cycles (Fitch-Roy et al., 2020; Moraga et al., 2019). In the French wine sector, this has translated to increased valorization of vineyard waste (e.g., damaged grapes, grape seeds, wine residues, etc.), rather than implementing a radical, transformative practice like designing out, e.g., unsustainable bottle shapes, weights, and material compositions. While both approaches can be valuable and do have their place, it is important to ensure that the utilization of these vineyard wastes does not lead to the homeostatic notion that enough is being done – curbing ambition for further efforts – and that repurposing this waste is not taking the time and other limited human and natural resources that could be better applied to a higher-circularity strategy in the winemaking process, as outlined in the previous section. Most organizations will follow regulations at the most basic level possible because it likely costs the least, and is simplest for integrating into current practices – meaning, if regulations allow space to only optimize, this is likely the pathway that will be taken – and the French wine sector will continue with business-as-usual linear business models. For this reason, we call on governments and policymakers to implement improved, refined policies in CE to facilitate more progress in this wine transition.

6.4. DISCUSSION

We found that strengths of the CDMT include offering directionality in decisions and helping to identify relevant questions at appropriate times. Additionally, we learned that the CDMT application may lead to the recognition of drivers and barriers in general and in a particular sector – which can be useful to practitioners and researchers in other sectors lacking in transformative practices – by walking step-by-step through the tool. The tool does also have its limitations. It does not explicitly weigh energy requirements, for which reason we recommend our study be paired with other work on sustainability in European wine-producing countries – like that of Campos et al. (2019) on prosumerism and sustainable energy practices in Mediterranean wine regions. The CDMT does not explicitly integrate the social dimension of sustainable development, excluding e.g., implications for labor force, both of which might prove to be important

factors in terms of practical implementation. In the same vein, our analysis identified barriers to social acceptance and funding – but it was not within the scope of our exploratory illustration to solve how to overcome e.g., informal quality regulations through the market. For this, we recommend that a social psychologist or economist couple their work with that of the CDMT to create a fuller picture. Lastly, quantitative data was unavailable at this time (in part, due to the generalization of databases already noted), and our work's exploratory nature and time constraints did not allow for field work to fit within the scope of this study. We recommend that future researchers build on this first work and test the CDMT empirically, to examine whether expectations from our results about the possibility for implementation translate into practice.

This research taught us that the CDMT can serve to exemplify how a decision might be made in CE. The framework can also help avoid linear optimizations that reinforce the current economy regime, which have in many instances otherwise been considered "circular". We see through the application of the CDMT that the "most circular" options are to be considered first, particularly before making a monetized demand for a waste – a waste which in many cases need not exist in the first place. The CDMT application helps us understand what might be going wrong in the sector now, and how we might arrive at more circular alternatives; it does not give an exact value quantitatively of which innovation should be selected and its calculated environmental impact. In some cases, the waste valorization described in the introduction may still be "worth it" – if doing so does not absorb the human, financial, and other resources that could otherwise be used to develop more transformative practices instead. This, in fact, is the goal of the CDMT: to prioritize innovations based on higher-level contributions to CE. If additional resources remain, or designing out the waste is not found to be possible, then the tree would lead to these lower-quality circularity options over no efforts at all. Yet, without proper key indicators in this field – as noted in the previous subsection – it is difficult to make any kind of measurement of progress in the state of the circular economy transition in the French wine sector. Accordingly, we recommend based on our results that expert practitioners in the (French) wine sector and circularity experts collaborate to co-design key factors and indicators that would be good representations of circular practices and possibilities in this sector, so that both fields of expertise are correctly incorporated into the design.

We learned that the user of the CDMT framework will still encounter tradeoffs at decision points. The tool does not eliminate tradeoffs, and it intentionally does not explicate what answer to choose at tradeoffs. This is because users may have differing secondary values (beyond higher-quality circularity) from each other. In this work's example, how many times are the bottles expected to be reused? What type of fuel

will the transportation be using to deliver the wine? Is it more important to eliminate plastic or glass entirely? The answer to these and other questions could change the user's desired choice and which innovation in the end might make a greater sustainable impact. For example, despite PCR PET being comprised of 10-100% post-consumer resin, i.e., recycled content, one might argue against the use of PET – whether from recycled or virgin sources – altogether. This use then must be weighed against the fossil fuels it is expected to avoid through lessening the transportation fuel necessary. The discussion about variables that may differ per case could go on for quite some time, and the CDMT is not designed to integrate such complex aspects of decision-making. The CDMT does offer the function of bringing to light these tradeoffs and allowing practitioners to maintain autonomy in their decision-making while incorporating this tool as support – in combination with which they can apply local knowledge about variables in their case, e.g., the percentage of PCR content in their bottles and the type of fuel used in transport. The framework is designed to help its users ask relevant questions in an appropriate sequential order, and each user then is allowed the capacity to choose for themselves what they value most during circular decision tradeoff points.

The illustration of the framework in this paper supported the notion that there is no clear-cut path to circularity, and there are no uncontested right answers for which innovations will be most transformative and have the highest impact in practice. We also learned that these outcomes may sometimes depend on variables that could not be captured in the tree. For this reason, we offer the CDMT not as a prescriptive tool, but as a decision-making framework that can be helpful in guiding decision-makers through questions in the right order. Often, asking the right questions can lead to better answers; from our results, we find that the CDMT helps in formulating some of these crucial questions and in a sequence that favors anticipating the circular impact an innovation, intervention, or policy may have.

6.5. CONCLUSIONS

This paper has reported the findings of an exploratory study that examined the potential utility of the CDMT – one non-R&D intervention strategy in circular economy –, as well as reflected on sector-specific barriers to CE in French wine, and further reflected on potential facilitators (to address some of these barriers) from the illustration of the CDMT. There are still few clear transformative activities in the French wine sector (at least documented in science), and it remains unclear which strategies will have which impacts. To answer the question of how we can potentially facilitate increased attention for and progress in CE within the French wine sector, we applied this new circular decision-making framework based on CDM logics and contributing to avoiding

linear path dependencies through increased awareness of higher-quality circularity contributions. Through this exploration, we aimed to contribute both to scientific discourse and practice, which we reflect on in the following concluding messages.

Our research was studied through a transition lens and informed by the WRP. We applied the CDMT framework to explore the lack of discussion, implementation, and circularity progress in the French wine sector. The logic within this framework prioritizes circular decision-making over optimizations of linear economy and based on linear assumptions. Through the illustration of the framework application, we addressed a call from previous CE researchers to explore sector-specific barriers to CE – in our work, the French wine sector. Because this paper's objective was to offer a sectoral illustration of how the CDMT could be applied, we did not a comprehensive list of barriers; in a real-life setting, a practitioner or researcher may choose to continue with this part of the analysis more extensively. We then used the named barriers to catalyze thinking around respective facilitators of circular practices in the French wine sector, and we described some of these facilitators that may encourage higher-quality CE implementation in the French wine sector. The results of our work may also have implications outside of our selected context – for other sectors with slow or no progress in circularity –, that might also potentially reap useful insights through the adoption and implementation of the CDMT.

From our findings, and building on the results of Greer et al., *under review* (on the original testing for validity of the CDMT), we posit that applying the CDMT in the French wine sector could facilitate coherency and a shared understanding between actors and institutions with respect to their primary goal for sustainability. In this way, the CDMT could also serve as a mapping, orientation, meta scheme, or communication tool for transparency within the organization, supply chain, or partnerships – to understand common values and goals to potentially create a stronger and clearer roadmap to a more circular future: an avenue we encourage future research to explore. The application of the CDMT in this exploratory study taught us what the framework can and cannot do, showed us some of its strengths and weaknesses, and offered us learnings about the transition to circular economy in general and how decision-making places a role in this transition. In conclusion, it can be said that this research fulfills its exploratory purpose to provide valuable insights into the potential usefulness of the CDMT as a practical tool for walking through decisions in circular economy, as well as to shed light on relevant barriers of and corresponding facilitators to CE in the French wine sector.

6.6. REFERENCES

Afonso, I. M., Ferraz, A., Rodrigues, A. S., Vale, A. P., Mendes, S., Alonso, J., ... & Rodrigues, A. C. (2018). Circular Economy in the Wine Sector: assessment of the potential of seeds of Portuguese grape varieties for oil production and by-products development. *Food Research International*, *50*, 161-166.

Aleixandre, J. L., Aleixandre-Tudó, J. L., Bolaños-Pizarro, M., & Aleixandre-Benavent, R. (2016). Viticulture and oenology scientific research: the Old World versus the New World wine-producing countries. *International Journal of Information Management,* 36(3), 389-396.

Ashby, B. (2008). THE FRENCH WINE INDUSTRY. *Consortium Journal of Hospitality & Tourism*, 13(1).

Ashenfelter, O., & Storchmann, K. (2016). Climate change and wine: A review of the economic implications. *Journal of Wine Economics,* 11(1), 105-138.

Audet, R., Lefèvre, S., Brisebois, É., & El-Jed, M. (2017). Structuring tensions and key relations of montreal seasonal food markets in the sustainability transition of the agri-food sector. *Sustainability*, *9*(3), 320.

Baiano, A. (2021). An Overview on Sustainability in the Wine Production Chain. *Beverages*, *7*(1), 15.

Berardi, P. C., & Dias, J. M. (2019). How Has the Wine Sector Incorporated the Premises of Circular Economy?. *Journal of Environmental Science and Engineering B*, *8*, 108-117.

Blomsma, F., & Brennan, G. (2017). The emergence of circular economy: a new framing around prolonging resource productivity. *Journal of Industrial Ecology*, *21*(3), 603-614.

Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2017). *Cost-benefit analysis: concepts and practice*. Cambridge University Press.

Bois, B., Rega, M., & Juban, Y. (2021). La viticulture durable vue à travers le prisme de 90 ans de résolutions de l'OIV. *Territoires du vin,* (12).

Borsellino, V., Schimmenti, E., & El Bilali, H. (2020). Agri-food markets towards sustainable patterns. *Sustainability*, *12*(6), 2193.

Campos, I., Marín-González, E., Luz, G., Barroso, J., & Oliveira, N. (2019). Renewable Energy Prosumers in Mediterranean Viticulture Social–Ecological Systems. *Sustainability*, *11*(23), 6781.

Chatel, G., Draye, M., Piot, C., Besombes, J. L., Fanget, P., Duwald, R., ... & Quinty, V. (2021). Valorisation de déchets et coproduits dans un contexte d'économie circulaire: de l'innovation académique au développement de projets de territoire. In *Journées Condorcet*.

Chertow, M. R. (2000). Industrial symbiosis: literature and taxonomy. *Annual review of energy and the environment*, *25*(1), 313-337.

Comité Champagne. (2015). Sustainable Development: Preserving and enhancing terroir, biodiversity and landscape; Confronting the energy/climate challenge. Accessed on 21 December 2021 from https://www.champagne.fr/en/sustainable-development/energy-climate-challenge

Cooper, J. (2019). Briefing: Developing a more circular economy model for wine packaging and delivery. In *Proceedings of the Institution of Civil Engineers-Waste and Resource Management* (Vol. 172, No. 2, pp. 40-41). Thomas Telford Ltd.

Croonenbroeck, C., & Lowitzsch, J. (2019). From fossil to renewable energy sources. In *Energy Transition* (pp. 29-58). Palgrave Macmillan, Cham.

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

de Orduna, R. M. (2010). Climate change associated effects on grape and wine quality and production. *Food Research International,* 43(7), 1844-1855.

Delmas, M. A., & Lessem, N. (2017). Eco-premium or eco-penalty? Eco-labels and quality in the organic wine market. *Business & Society*, 56(2), 318-356.

Dóci, G., Vasileiadou, E., & Petersen, A. C. (2015). Exploring the transition potential of renewable energy communities. *Futures*, *66*, 85-95.

Ellen MacArthur Foundation. (2021). Accessed on 21 December 2021 from https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

European Commission, (2021). A European Green Deal: Striving to be the first climate-neutral continent. Accessed on 21 December 2021 from https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

European Environmental Bureau. (2021). One year of the EU's Circular Economy Action Plan. Accessed on 21 December 2021 from https://eeb.org/one-year-of-the-eus-circular-economy-action-plan/

European Union (2008). Directive 2008/98/EC of the European Parliament and the Council of 19 November 2008 on Waste and Repealing Certain Directives. *Official Journal of the European Union,* 22/11/2008.

Eurostat (2020). Wine production and trade in the EU. Accessed 27 October 2021, from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20201119-2

Fayolle, E., Follain, S., Marchal, P., Chéry, P., & Colin, F. (2019). Identification of environmental factors controlling wine quality: A case study in Saint-Emilion Grand Cru appellation, France. *Science of the Total Environment*, *694*, 133718.

Fitch-Roy, O., Benson, D., & Monciardini, D. (2020). Going around in circles? Conceptual recycling, patching and policy layering in the EU circular economy package. *Environmental Politics*, *29*(6), 983-1003.

Friant, M. C., Vermeulen, W. J., & Salomone, R. (2021). Analysing European Union circular economy policies: words versus actions. *Sustainable Production and Consumption*, *27*, 337-353.

Galitsky, C., Worrell, E., Radspieler, A., Healy, P., & Zechiel, S. (2005). BEST Winery Guidebook: Benchmarking and Energy and Water Savings Tool for the Wine Industry.

Garcia-Casarejos, N., Gargallo, P., & Carroquino, J. (2018). Introduction of renewable energy in the Spanish wine sector. *Sustainability*, *10*(9), 3157.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), 1257-1274.

Geels, F. W. (2014). Regime resistance against low-carbon transitions: introducing politics and power into the multi-level perspective. *Theory, culture & society*, *31*(5), 21-40.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy*, *36*(3), 399-417.

Grafström, J., & Aasma, S. (2021). Breaking circular economy barriers. *Journal of Cleaner Production*, *292*, 126002.

Greer, R., von Wirth, T., & Loorbach, D. (2020). The diffusion of circular services: Transforming the Dutch catering sector. *Journal of Cleaner Production*, *267*, 121906.

Greer, R., von Wirth, T., & Loorbach, D. (2021). The waste-resource paradox: Practical dilemmas and societal implications in the transition to a circular economy. *Journal of Cleaner Production*, *303*, 126831.

Greer, R., von Wirth, T., & Loorbach, D. (*under review*). The Circular Decision-Making Tree: An operational heuristic. *Accepted for publication, in revision.*

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

Hebinck, A., Klerkx, L., Elzen, B., Kok, K. P., König, B., Schiller, K., ... & von Wirth, T. (2021). Beyond food for thought–Directing sustainability transitions research to address fundamental change in agri-food systems. *Environmental Innovation and Societal Transitions*.

Hina, M., Chauhan, C., Kaur, P., Kraus, S., & Dhir, A. (2022). Drivers and barriers of circular economy business models: Where we are now, and where we are heading. *Journal of Cleaner Production*, 333, 130049.

Jaeger, R. G., & Halliday, T. R. (1998). On confirmatory versus exploratory research. *Herpetologica*, S64-S66.

Kallis, G., & Norgaard, R. B. (2010). Coevolutionary ecological economics. *Ecological economics*, *69*(4), 690-699.

Kelly, L. M., & Cordeiro, M. (2020). Three principles of pragmatism for research on organizational processes. *Methodological innovations*, *13*(2), 2059799120937242.

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

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of cleaner production*, *175*, 544-552.

Landi, D., Germani, M., & Marconi, M. (2019). Analyzing the environmental sustainability of glass bottles reuse in an Italian wine consortium. *Procedia CIRP*, 80, 399-404.

Lereboullet, A. L., Beltrando, G., & Bardsley, D. K. (2013). Socio-ecological adaptation to climate change: A comparative case study from the Mediterranean wine industry in France and Australia. *Agriculture, ecosystems & environment*, 164, 273-285.

Liedtke, C., Baedeker, C., Hasselkuß, M., Rohn, H., & Grinewitschus, V. (2015). User-integrated innovation in Sustainable LivingLabs: An experimental infrastructure for researching and developing sustainable product service systems. *Journal of Cleaner Production*, *97*, 106-116.

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures*, *42*(3), 237-246.

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.

Loorbach, D., Wittmayer, J., Avelino, F., von Wirth, T., & Frantzeskaki, N. (2020). Transformative innovation and translocal diffusion. *Environmental Innovation and Societal Transitions*, *35*, 251-260.

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research policy*, *41*(6), 955-967.

Martínez-Lüscher, J., Kizildeniz, T., Vučetić, V., Dai, Z., Luedeling, E., van Leeuwen, C., ... & Delrot, S. (2016). Sensitivity of grapevine phenology to water availability, temperature and CO_2 concentration. *Frontiers in Environmental Science*, 4, 48.

Mbaka, N., & Isiramen, D.O.M. (2021). The changing role of an exploratory research in modern organisation. *Gph - International Journal of Business Management (IJBM)*, *4*(12), 27-36. Retrieved from http://www.gphjournal.org/index.php/bm/article/view/524

McDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., ... & Doménech, T. (2017). Circular economy policies in China and Europe. *Journal of Industrial Ecology*, *21*(3), 651-661.

McGovern, P. E., Luley, B. P., Rovira, N., Mirzoian, A., Callahan, M. P., Smith, K. E., ... & Henkin, J. M. (2013). Beginning of viniculture in France. *Proceedings of the National Academy of Sciences*, 110(25), 10147-10152.

McWilliam, W., & Wesener, A. (2021). Attitudes and behaviours of certified winegrowers towards the design and implementation of biodiversity farming strategies. *Sustainability*, *13*(3), 1083.

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., ... & Dewulf, J. (2019). Circular economy indicators: What do they measure?. *Resources, Conservation and Recycling*, *146*, 452-461.

Mozell, M.R.; Thach, L. (2014). The impact of climate change on the global wine industry: Challenges & solutions. *Wine Econ. Policy* 2014, *3*, 81–89.

Ollat, N., Touzard, J. M., & van Leeuwen, C. (2016). Climate change impacts and adaptations: New challenges for the wine industry. *Journal of Wine Economics*, 11(1), 139-149.

Ranta, V., Aarikka-Stenroos, L., Ritala, P., & Mäkinen, S. J. (2018). Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe. *Resources, Conservation and Recycling*, *135*, 70-82.

Raymond, C. M., Williams, D. R., Di Masso, A., Manzo, L. C., & Von Wirth, T. (2021). Introduction: senses of place in the face of global challenges. *In: Raymond, CM; Manzo, LC; Williams, DR; Di Masso, A.; von Wirth, T., eds. Changing senses of place: Navigating global challenges. Cambridge University Press. p. 1-18. Online: http://www.cambridge.org/9781108477260,* 1-18.

Renaud, B. (2019). Les coproduits de l'industrie agroalimentaire au regard des politiques publiques: bioéconomie, économie circulaire, gaspillage alimentaire. In *Le Déméter 2019* (pp. 277-296). IRIS éditions.

Rijksoverheid. (2022). Nederland circulair in 2050. Accessed on 1 May 2022 from https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050

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

Rivera, O. M. P., Leos, M. D. S., Solis, V. E., & Domínguez, J. M. (2021). Recent trends on the valorization of winemaking industry wastes. *Current Opinion in Green and Sustainable Chemistry*, 27, 100415.

Rogers, E.M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Santillán, D., Garrote, L., Iglesias, A., & Sotes, V. (2020). Climate change risks and adaptation: New indicators for Mediterranean viticulture. *Mitigation and Adaptation Strategies for Global Change*, 25(5), 881-899.

Santos, J. A., Fraga, H., Malheiro, A. C., Moutinho-Pereira, J., Dinis, L. T., Correia, C., ... & Schultz, H. R. (2020). A review of the potential climate change impacts and adaptation options for European viticulture. *Applied Sciences*, 10(9), 3092.

Sartorius, C. (2006). Second-order sustainability—conditions for the development of sustainable innovations in a dynamic environment. *Ecological Economics*, *58*(2), 268-286.

Sazdovski, I., Bala, A., & Fullana-i-Palmer, P. (2021). Linking LCA literature with circular economy value creation: A review on beverage packaging. *Science of The Total Environment*, 145322.

Schor, J. (2016). Debating the sharing economy. *Journal of self-governance and management economics*, *4*(3), 7-22.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology analysis & strategic management*, *20*(5), 537-554.

Schultz, H. R. (2016). Global climate change, sustainability, and some challenges for grape and wine production. *Journal of Wine Economics*, 11(1), 181-200.

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

Sette, P., Fernandez, A., Soria, J., Rodriguez, R., Salvatori, D., & Mazza, G. (2020). Integral valorization of fruit waste from wine and cider industries. *Journal of Cleaner Production,* 242, 118486.

Seyfang, G., & Haxeltine, A. (2012). Growing grassroots innovations: exploring the role of community-based initiatives in governing sustainable energy transitions. *Environment and Planning C: Government and Policy*, *30*(3), 381-400.

Smith, A., Voß, J. P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research policy*, *39*(4), 435-448.

Stahel, W.R. (2014). Reuse is the key to the circular economy. In: European Commission. Accessed on 1 May 2022 from http://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/reuse-is-the-key-to-the-circular-economy_en.

Stebbins, R. A. (2001). *Exploratory research in the social sciences* (Vol. 48). Sage.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the Anthropocene: the great acceleration. *The Anthropocene Review*, *2*(1), 81-98.

Stigler, G. J. (1958). The economies of scale. *The Journal of Law and Economics*, *1*, 54-71.

Stuckrath Alvarado, C. T. (2020). *Circular business models and packaging through the supply chain: a Chilean wine industry case study* (Master's thesis).

Tukker, A., & Butter, M. (2007). Governance of sustainable transitions: about the 4 (0) ways to change the world. *Journal of Cleaner Production*, *15*(1), 94-103.

Valero, A. E., Howarter, J. A., & Sutherland, J. W. (2019). Sustainable Wine Scoring System (SWSS): A life cycle assessment (LCA) multivariable approach. In *BIO Web of Conferences* (Vol. 12, p. 03016). EDP Sciences.

van Leeuwen, C., & Darriet, P. (2016). The impact of climate change on viticulture and wine quality. *Journal of Wine Economics*, *11*(1), 150-167.

van Leeuwen, C., & Destrac-Irvine, A. (2017). Modified grape composition under climate change conditions requires adaptations in the vineyard. *Oeno One*, 51(2-3), 147-154.

van Leeuwen, C., Destrac-Irvine, A., Dubernet, M., Duchêne, E., Gowdy, M., Marguerit, E., ... & Ollat, N. (2019). An update on the impact of climate change in viticulture and potential adaptations. *Agronomy*, 9(9), 514.

Venios, X., Korkas, E., Nisiotou, A., & Banilas, G. (2020). Grapevine responses to heat stress and global warming. *Plants,* 9(12), 1754.

Vermunt, D. A., Negro, S. O., Van Laerhoven, F. S. J., Verweij, P. A., & Hekkert, M. P. (2020). Sustainability transitions in the agri-food sector: How ecology affects transition dynamics. *Environmental Innovation and Societal Transitions*, *36*, 236-249.

Villanueva-Rey, P., Vázquez-Rowe, I., Moreira, M. T., & Feijoo, G. (2014). Comparative life cycle assessment in the wine sector: biodynamic vs. conventional viticulture activities in NW Spain. *Journal of Cleaner Production*, 65, 330-341.

von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229-257.

Wilson, J. E. (1998). *Terroir: The role of geology, climate and culture in the making of French wines.* Univ of California Press.

Winkler, A. J. (1974). *General viticulture.* Univ of California Press.

World Bank. (2018, September 20). Global Waste to Grow by 70 Percent by 2050 Unless Urgent Action is Taken: World Bank Report. Accessed on 21 December 2021 from https://www.worldbank.org/en/news/press-release/2018/09/20/global-waste-to-grow-by-70-percent-by-2050-unless-urgent-action-is-taken-world-bank-report

7

CONCLUSIONS: LESSONS AND OUTLOOK ON TRANSITIONING TO A CIRCULAR ECONOMY

In this thesis, I have studied the transition to a circular economy, exploring if and how interventions linked to the circular economy may become transformative or not. My thesis additionally addressed circular entrepreneurship in the niche and regime contexts. More specifically, I investigated and described 15 principles for empowering niche activities while engaging regime incumbents as potential pathways towards advancing the transition, and I critically examined circular business models and innovations that may involve traps and pitfalls to paradoxically reinforce linear path dependencies, by increasing the strength and resistance of the current economic systems in place. Further, I explored the potential for increasing capacities for transformative governance within the transition to a circular economy, developed a new governance logic, and applied it to the wine sector (which is still largely basing decisions on a linear decision-making logic) to offer insights for future strategies.

7.1. THE CURRENT STATE OF TRANSITION TO A CIRCULAR ECONOMY AND RELATED PARADOXES

Through my PhD, it became clear that we are still in the early stages of the transition to a circular economy. The interpretation of, knowledge about, and understanding of the concept of CE ranges from unheard of in some countries and sectors to prominent aspects of national and international policy in others, like in the EU's broader mission to transition to CE and the Netherlands in particular striving to become fully circular by 2050. To that end, there are promising signs of circular experimentation, entrepreneurship, and related research increasingly emerging in recent years. Yet, despite these promising goals, attention for, and policies surrounding circular economy, we are still quite far from establishing this alternative paradigm as the norm for business operations and society at large. This may be in large part due to the inherent and great uncertainties involved in transitioning from one economic system and way of living to a wholly new one, which have been discussed in the previous chapters of this dissertation. Over the course of my research, a number of paradoxes that emerge within the transition to a circular economy – and may slow or inhibit its acceleration – became evident:

Paradox #1: Increasing circular initiatives, but decreasing overall circularity.

Increasing numbers of circular initiatives (groups of people experimenting with alternative more circular practice) are forming; yet, we are paradoxically becoming increasingly *less* circular with time in recent years. This is according to the reputable World Circularity Report – which attempts to evaluate our world circularity level – and measured us to be 8.6% circular in 2021 Circularity Gap Report, while actually being

9.1% circular two years prior in 2019 (Circularity Gap Report, 2021). While there may be debates around calculations made or embedded assumptions within this specific result, it can still be clearly said that we have not integrated significant systemic change towards a more circular future vision. Despite all the activities, experiments and diverse funding streams going into circular models, the transition appears to be stuck or slowed down and has further barriers to overcome that need to be described with future research and addressed with practical solutions. I hypothesize that the number and strength of circular initiatives are indeed growing, but overconsumption and production are growing in parallel at an even stronger rate. This would indicate the push for circularity should be even further strengthened to match up against and attempt to destabilize the current and increasing strength of linear practices.

Paradox #2: Inherent tradeoffs between the sustainability pillars of circular economy.

Central principles of the circular economy include the least virgin material extraction from the earth and preservation of or increasing social justice overall. Yet, by e.g., recycling waste electronics and saving precious metals that could otherwise have been lost in landfills – a clear environmental benefit – many people living near informal recycling centers are being put in danger: exposed to dangerous toxins that negatively impact both the workers' and entire community's respiratory, cardiovascular, and reproductive systems health. Paradoxically, an attempt to increase circularity of one pillar of sustainability may decrease or counteract its circular contribution in another pillar. This highlights the tradeoff between pillars of sustainability that may occur within the transition to a circular economy, which by definition should take a net-positive integrated approach to these elements. Perhaps it is not possible to make every circular initiative net positive for all three pillars of sustainable development and circularity together, but my research indicates that we should be cautious not to overlook an uncontested and significant sacrifice of one (e.g., social justice) for another (e.g., environmental sustainability) – keeping in mind the three-prong goal of CE when implementing initiatives as endeavors to approach CE. Similarly, tradeoffs may occur at another nexus, e.g., economic-social or environmental-economic. The transition to a circular economy is a balancing act of all three, indicating the need to consider tradeoffs carefully, also excluding some activities that do not fit within the integrated standard.

Paradox #3: Cross-scale circularity rebound effects.

Similarly, questions of scale can expose pitfalls and traps when considering the "circularity" of a place or organization with different scopes or various lenses or

magnifications. While some cities may exhibit statistically exemplary levels of circularity, that result may not be as valid when considering the broader system to which they pertain and any outsourcing of unsustainabilities involved. The paradox lies in the potential for achieving a fully circular city – when considered at that specific scale – that may actually have a rebound effect and *decrease* global circularity if truly transformative systems and solutions are not in place, by outsourcing (and potentially increasing) unsustainable materials, processes, and practices to surrounding areas. If a city keeps its current linear systems in place – but optimizes and outsources their waste – then the production, consumption, and waste may remain the same as before, but additional resources must be consumed to transport them out of the city, making the broader system scope even more dependent on the embedded linear systems and resource consumption styles.

Paradox #4: Tradeoff between potential for uptake and potential for transformation.

Another paradox present in the transition to a circular economy is that a single "circular" product or process encounters less resistance to be taken up to the regime than an entire shift in services; yet, the less resistance encountered in being taken up by the regime also increases the risk that the innovation contributes to optimization of the current regime, rather than changing it entirely. In contrast, ecosystems of interconnected circular niche entrepreneurs that are all interdependent of each other – but, together, constitute a circular service may have more transformative potential for altering incumbent structures, cultures, and practices, because they are an experimentation of what a mini-CE could look like in one particular sector or industry, with already demonstrated effectivity as a cohesive, functioning system in their niche context. By having more complexity than a single entrepreneur or product alone, these systems may be more likely to stay in place at a regime level once breaking through. Yet, more complex systems face more resistance compared to single products in breaking through to the regime, while more likely to offer a realistic alternative to regime practices services. This paradox may make it difficult to pre-determine which type of circular innovation could create the most meaningful impact.

Paradox #5: Some circular attempts increasing linear path dependencies.

Another key paradox encountered within my PhD is: with increasing experimentation and acceleration of circular policies and business models, some of these – no matter how well-intentioned – may prove to be counter-transformative by increasing linear path dependencies and further entrenching us in linear practices. I observed this to

be potentially related to a oversight of thinking on a systemic level and narrowing in on only one partial element of what (under the right conditions) can be a characteristic of CE: closing loops. If these innovations provide an incentive to continue with linear processes that could otherwise be radically transformed, in a twisted fate, they are actively working against the transition they aim to accelerate.

Paradox #6: The goal of acceleration potentially reducing the integrity of the innovation's radicality.

Within a niche context, these ideas and innovations experience protection by being shielded, nurtured, and empowered in their level. When scaling up to a regime level, they may break path dependencies, but they may also be assimilated within unchanged selection environments, rendering their original radicalness tepid. In this case, it likely does not make an impact on destabilizing or fundamentally changing the current linear regime and results only in optimization. This is one demonstration of how putting better systems and structures in place may help to preserve the integrity of the innovation taken up so that it does not paradoxically lose its alternative nature to the regime at the same time that it breaks through to the regime that it aims to change.

Paradox #7: Traditional transition dynamics displaying counter-intuitive behavior.

The concepts of both the regime-niche and niche-regime are inherently oxymoronic. In part of a transition, niches come together to form clusters, creating their own regime – the very idea that they are, in principle, alternatives to. Reciprocally, there are proactive/hybrid actors acting as small niches within the incumbent regime context that begin to think progressively and independently. These paradoxical exceptions to the more general descriptions of the niche and regime can be found in the unique transition space between a transforming old regime and an emerging new regime – the heart of a transition.

From the seven paradoxes I identified in my research as surfacing in the transition to a circular economy, it became clear that strategizing and decision-making in this context is highly uncertain, and pathways are not straightforward. On a conceptual level, even the normally clearly defined transition elements like niche and regime begin to morph and take part in unpredictable dynamics with unpredictable behavior. In the following section, I address some of these tensions and uncertainties with key lessons learned as a result of my dissertation research.

7.2. MAIN CONTRIBUTIONS OF THE THESIS TO THE CIRCULAR ECONOMY TRANSITION

My PhD research has offered some empirical and conceptual contributions related to different dimensions of the circular economy transition. Figure 9 summarizes the findings of my contributions in their order of development during my research:

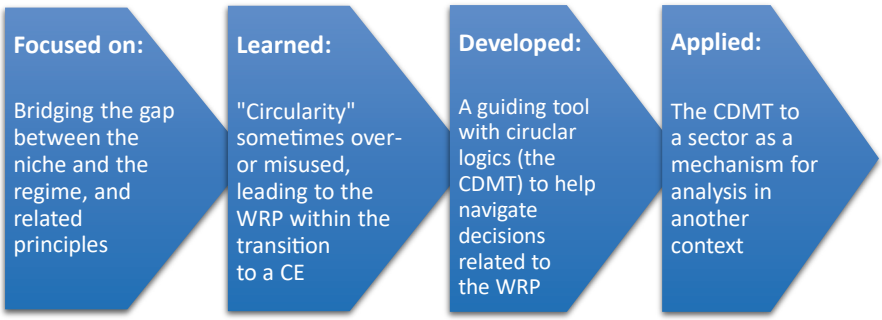


Figure 9: PhD structure

In the following three subsections (7.2.1, 7.2.2, 7.2.3), I describe insights from each of my thesis chapters that relate to various dimensions of the transition to CE: the niche/regime dimension, the waste/resource dimension, and the decision-making dimension, respectively. I use these as lenses to approach the transition to a circular economy in the fourth subsection (7.2.4), where I take the learnings from across my PhD and apply the lenses to a specific sector to test the vision.

7.2.1. Crossing the niche/regime gap

Corroborating common findings of other transitions research, in my research, I observed that there are many differences between niche and regime elements that put up potential barriers to transition. For example, differences in language, capacities, networks, skills, and resources between niche and regime elements must be overcome to allow space for the acceleration of a transition. Yet, there is still little effectuated in practice or known about how to foster this bridging, particularly in the context of circularity and circular services. Based on this, I hypothesized that there was a lack of mechanisms to facilitate cooperation, exchange, and translation between niche and regime dynamics. In order to explore these gaps and develop potential enabling mechanisms, I conducted an empirical case study with my colleagues in Rotterdam of the scaling up of circular catering service to a ministry level. In that study, we explored how circular niche innovations and actors can connect with incumbent actors and institutions, and how favorable settings for fostering transition space can be created.

From this, we gleaned 15 principles for connecting regime elements with niche innovations and categorized these according to the four analytical characterization types from Smith (2007)'s related framework on niche emergence, regime tensions, and interactions between these elements.

Describing these practices offered various contributions to science and practice. Firstly, we offered an in-depth look at a unique phenomenon – regime organizations (government and other multi-national companies) actively seeking out, adopting, and succeeding in implementing a potentially transformative radical circular service innovation on a national scale and beyond – and documented it in a novel regime-niche framing. An inside look on this case facilitated a better understanding of the inner workings and transition dynamics involved in a "live" ongoing scaling up of a niche service to a regime level. Observing this in real time opened up insight into how to potentially create settings and scenarios that may foster the creation and scaling up of circular services in other sectors and industries, helping to facilitate a more widespread reach for the acceleration of the larger transition to a circular economy more generally. Further, identifying these practices that prime the setting for niche and regime elements to connect offered a basis for direction to both of these elements on how to gain exposure to and connect with their complementary value-aligned transition counterpart and form a promising symbiosis.

The fifteen principles for connecting niche ideas with regime institutions described in my research may enable companies, organizations, governments, universities, entrepreneurs, and other actors and institutions to increase activities related to these principles to encourage empowerment of niche concepts and engaging regime elements. The illustrative examples collected and offered in my research of the observed practices found to foster connections between the niche and the regime can enable other institutions and industries to replicate and adapt these practices into their own contexts, in a way potentially generalizable to myriad sectors and services in their respective empirical domains. Reflecting on observations I made after conducting eleven semi-structured, in-depth interviews for this case study, I also described a perspective on transformative capacities and potential at the regime level that may enable researchers, entrepreneurs, and practitioners to be more open to seeing regime actors and organizations as co-creators in the transition to a circular economy.

I found one of the resulting principles, the importance of influential and informative narratives, particularly interesting to me for its ability to soften a potentially high-friction resistance from a top-down implementation initiative to an initiative that was well-respected and greatly helped in common goal framing and formation. I hypothesize

that this could similarly have a widespread and impactful effect on public opinion, so I can only recommend more research on the formation and dissemination of effective narratives that may incite awareness and motivation towards the movement of CE in the masses.

This case also taught a lesson about responsible governance and power. In the case of circular catering in the Netherlands, the "top-down influences/pressures" – (I would now add the word "incentives" to this observed practice) – were an important and effective catalyst in the uptake and scaling of a circular service to a national scale, because a high governing body aligned with and effectuated actions that contributed to the Dutch national goal of being fully circular by 2050. However, in another context, a regime-level governmental organization that is theoretically motivated to maintain current linear economics because of vested interests or other path dependencies could have the reverse intended effect and bolster barriers against the transition to a circular economy. For this reason, these principles should be tested in other contexts for generalizability, and any replication of the principles should be in a discerning way to adjust for context variables.

It may also be important to consider practices in conjunction with each other. For example, the "First order lessons" learning practice of "Creating/assessing awareness [about circularity]" does not necessarily translate into any meaningful contribution to accelerating circular services in transition to a CE, but it becomes meaningful when practiced in combination with the "Second order lessons" analytical learning category's principle of *acting* upon that assessment. Reciprocally, no action can be taken on an assessment of awareness if no baseline assessment has first been made. Considering these principles and practices in a broader context, it is worth noting that there may be dilemmas created by some of the observed practices for accelerating circular innovations. For example, the practice of "Improving the accessibility of a waste as a resource" directly leads to the Waste-Resource Paradox, as described in Chapter 4, which may have unintended negative consequences for the transition to a circular economy, if the uncertainty around this paradox is not navigated intelligently.

Furthermore, as the transition to a circular economy continues to develop, we may observe new (or current, and not uncovered in this case), additional connecting principles emerge. Thus, there may also be future principles uncovered that are not described here. This could particularly be the case as more circular services are studied – as recommended by my thesis – and services outside the FEW (food-energy-water) nexus are studied, eliciting practices more dominant in their respective fields. Because these principles and practices were formulated to be mostly generalizable to other

types of circular services, I recommend research on other circular services scaling up in other fields and contexts, and I recommend practitioners to experiment with utilizing these practices as a means to scale up circular practices still operating at a niche level.

7.2.2. The Waste-Resource Paradox

In my thesis, I investigated how actors understand circularity and resources versus wastes. In that analysis, I encountered different meanings from different elements at different times and in different places, which is complicating the transition. Zooming out, the definitions also shifted; these contradictions created a paradox. In my thesis, I refer to this as the Waste-Resource Paradox (WRP), which I developed conceptually. To address this, I researched the different dilemmas encountered in different pillars of society resulting from the WRP, the systemic dynamics at play, related key considerations, and societal implications. I distinguished four societal dilemmas in which this key paradox manifested, which all have important implications for how we address this demarcation from a legal, business, environmental, and economic standpoint.

I defined the WRP as the phenomenon that a certain material at any time could be considered a waste or a resource and experience conflicts in simultaneous paradoxical considerations: depending on the perspective of the handlers, the practicality of its use at the end of life, the cultural and geographical context surrounding it, and the legal backdrop on which is it evaluated. It is further paradoxical because the innovations related to the WRP are generally designed to close loops, reduce waste, and advance the transition to a circular economy. However, these innovations may result in being counter-productive to CE by catalyzing a rebound effect of material use, creating a tradeoff with energy demand, bankrupting circular startups, and posing a risk to human health. Despite its widespread occurrence, until now the WRP has gone highly unnoticed and understudied – not yet fully conceptualized to date.

While the transition to a CE brings many tensions and uncertainties along with it, the perspective of the WRP helps to better differentiate the dilemmas and implications of some of these. Unpacking the dynamics, dilemmas, and implications of the WRP creates awareness about risks and tradeoffs of building novel business models upon waste as a commodity and the implications this has in the transformation to a circular economy. Furthermore, it allows policymakers, investors, and business owners to think through the long-term implications of innovations with circular intents, and what these could mean for the progression towards a sustainable, just circular economy. It offers a widened decision-making capacity in their role during the transition zone on the path from a linear towards a circular economy.

There are practical dilemmas involved in the WRP dynamics, which help illustrate tradeoffs in advance. For example, 3D printing with recycled plastic pellets can lead to material savings at the cost of high energy use. In a different illustration, informal recycling centers can save material, but at the cost of health and livelihoods of locals in the communities hosting these centers because of burning and toxic chemicals in the area. In various sectors, from food to plastic to energy to fashion, I identified tradeoffs in practice through the perspective of the WRP:

- Closing a material loop that incentivized future unnecessary overproduction of waste;
- Cascading and value retention that partially removed the financial disincentive of over-ordering (and thereby, overproduction);
- Reducing plastic waste that required a new high energy demand to process;
- Reducing food waste that directly caused an increase in transport and fuel consumption, due to the EU legal context;
- Creating a new use for an old waste, which may result in a potential commodification of waste and a new market barrier for circular entrepreneurs; and
- Secondary material recovery at a cost to human health and social justice.

In particular industries, I found that the legal definition of waste or the cumbersomeness of another structural procedure impeded the ability and feasibility of using a waste as a resource. As an example, in the food industry: as soon as a food-related byproduct leaves the walls of the building in which it was created, it is legally labeled a waste in the Netherlands. This can cause issues of accessibility for those innovators wanting to explore a way to close that loop and create logistical complications that result in an increase of energy demand and carbon emissions.

Identifying a WRP occurrence in practice may enable actors in practice to recognize a warning signal for an approaching rebound scenario. In this way, it may allow space to take preventative measures to curb or stop a potential related negative effect from occurring before it becomes embedded in society. The WRP illustrates the need for critical thinking on how to uphold quality and safety standards while improving environmental efficiency. Furthermore, it raises the discussion of if and in which form novel regulations and standards emerge during the transitionary period bridging the linear and circular economy regime shift. The inclusion of various sectors and materials experiencing the same WRP in various ways indicates that this is a phenomenon to consider in various fields and industries while navigating the uncertainty of the chaos transition dynamic that emerges in the instability between two regimes in a transition. Based on my research, I argue that awareness of the WRP can help during our societal

endeavor to transition from a linear to a circular economy to understand the potential long-term and systemic implications of turning a waste into a resource.

An additional social justice repercussion of the WRP, extending the dilemma described in Chapter 4, is the potential rise of theft in an area. For example, the second-generation Toyota Prius (innovated as a more sustainable alternative to traditional cars) has been reported by the Highway Loss Data Institute of the United States to be 40 times more likely to be subject to theft claims than the average vehicle (McCandless, 2021) – particularly due to an engine part highly valuable as scrap and easy to remove from the cars, the catalytic converter. The catalytic converter contains platinum, rhodium, palladium, and other precious metals that have recently risen in price due to low mining production in recent years. Because the engine piece – the selling of which is designed to be as a waste product at the end of life of the car or engine – can now be sold as a resource, this has also increased widespread theft. When navigating the WRP, exercising caution in valorizing a waste as a resource may help avoid wastes becoming economically valuable enough to encourage heightening crime rates, at the cost of the social dimension of CE.

The WRP is also relevant to economics research, as the valorization of wastes can affect the market, businesses, and the economy more generally. It is still unknown and unpredictable what percentage of all "wastes" will become commodified, so there is a wide range of potential impact this may have on the economy (and of course, the transition to a circular economy), so I recommend future researchers pick this up, building on my WRP work, to model the gravity of the effect the WRP is likely to have on the market. Furthermore, I recommend that the WRP be studied more closely as related to energy exchanges and waste energy valorization. This is a highly specific subject for research, but it would address the energy aspect of circular economy, and it would add an interesting additional facet of understanding about the WRP. I could find no work on this particular research inquiry, which would offer a complementary block of knowledge relevant to my research on transitions and circular economy, by also touching aspects of the energy transition. These two parts of the WRP would enable practitioners and circular economy researchers to implement more circular industrial symbioses – e.g., of waste steam produced by one industrial building that could be captured and utilized as power in another connected or nearby building or process – that should take the same cautionary messages discussed in Chapter 4 of the WRP illustrative examples relating to material input.

7.2.3. The Circular Decision-Making Tree

Despite national and international goals for transitioning to a circular economy in many countries, there is currently a lack of translating these CE visions meaningfully into transformative action. In my research, I found that current decision-making logics were based largely on linear assumptions, which feeds into the LE optimizations and further entrenches it as the incumbent structure. A new economic paradigm implies a new and radically different logic upon which to base decisions; a transition to a new form of economic operation cannot happen without first drastically changing our decision-making logics to be rooted in assumptions from the new paradigm underlying the system of operation. Navigating transitions requires systems thinking, which in turn requires envisioning a whole new system as the basis for decisions, not predicated on assumptions of and making small adaptations to, the current paradigm. This implies that decision-makers in practice need a different kind of logic and instrument. To answer the research question about how decision-makers in government and business can be supported in more effectively translating circularity visions into meaningful impact, I explored a new governance logic, designed a navigation tool to support decision-makers in operating this, and tested its logics through co-creative workshops in various socio-political contexts within my PhD project consortium.

To form a solid theoretical and applicable foundation for such a logic and to create a corresponding framework for navigating this logic, I conducted a thorough literature review around circular economy, decision-support tools, circular frameworks, national and international waste directives, and environmental assessment methods and modeling. Then, I compacted this knowledge into an interactive tool – which I called the Circular Decision-Making Tree (CDMT). The CDMT aimed to help navigate this circular decision-making logic, taking into consideration highest potential positive impact on the transition to circularity (independent of certain sectors or material types). As its underlying assumption, I implicitly defined the circular innovation with the most impact potential to be a combination of 1) the innovation with the highest-quality contribution to circularity (as indicated by LCAs, R-imperatives, etc.), and 2) the highest diffusion potential, considered together and in that order. Naturally, the assessment of these factors is dependent to some extent on assumptions made, where definitive quantitative data/modeling is not available.

Within the context of the Waste FEW ULL project – which was funded by the European Union's Horizon 2020 research and innovation program (within the Sustainable Urbanization Global Initiative), from JPI Urban Europe and the Dutch National Science Foundation (NWO) – our consortium aimed to research ways to substantially reduce waste inefficiencies in three continents: Africa, Europe, and South America. The four

Urban Living Lab partners (in the Netherlands, Brazil, South Africa, and the United Kingdom) linked to this project aim conducted group interviews and co-creative workshops with local researchers and practitioners to reflect together on how the CDMT might support decision-makers in government and business more effectively translate circularity visions into meaningful impact. The workshops indicated such a circular decision logic's ability to challenge incrementalism, to offer autonomy, and to improve co-creative decision-making. This new logic – and a tool to help navigate it – may offer insights to users about product design improvements, facilitate group management decisions, and add transparency throughout the value chain. Participants observed that the underlying logics of the CDMT stimulate reflexivity about the diversity of circular options and highlight the inherently differing quality levels of different waste streams and circular innovations, helping to identify dilemmas and drawing attention to the impact of upscaling. The practical way of supporting decision making was found to be transformative and actionable across different cultural contexts. This commonality across contexts may offer insight in the potential for replicability and generalizability of the tool's application.

The CDMT constitutes a new decision-making logic that I operationalized in my PhD research. It has been tested in different countries and different contexts, indicating a more general appetite for new instruments and approaches. It includes complementary tools at decision points outside the scope of the heuristic, e.g., a life cycle assessment for evaluating environmental impact or a cost-benefit analysis as an economic assessment, but it is not a substitute for such tools. The focus of the CDMT was to translate a circular decision-making logic into a tangible framework. Thus, very field-specific decisions were excluded, e.g., sustainable decision-making in the chemicals field, whose related researchers or practitioners may find a more appropriate tool catered to their objective.

The main contribution of this new decision-making logic is its challenging of current assumptions made in current linear contexts. Shifting logics are more congruent with the idea of a paradigm shift, because they would exclude incremental innovations and linear optimizations. Implementing and utilizing a new circular decision-making logic could reduce the following and further entrenching of linear path dependencies. The workshops have indicated this to work conceptually; yet, decisions made in practice will always be embedded in a political and market context, meaning other variables may influence or trump circularity concerns, potentially limiting the linear inertia disruption as a result. Actors often cannot exercise control over some of these external factors, but through the CDMT I offer one tool to equip them with new knowledge and potential strategies for moving forward in circular decisions.

7.2.4. Application of the lenses

Given the increasing pressures and stressors resulting from continued over-consumption and production on many sectors, I questioned why certain sectors are still not advancing in their transition to circularity. To study this more closely, I chose to analyze a sector directly impacted by effects of unsustainable practices: the wine sector – whose grapes are acutely vulnerable to fluctuations in temperature and moisture. It is still overlooked how to best strategize within complex and persistent environmental sustainability issues in this sector, given that many material-reducing practices in the wine sector focus on end-of-life solutions, and pathways to accelerate the transitions towards circular wine have not been sufficiently addressed in the scientific debate. To address the research question regarding what new insights the application of a circular decision-making tool in a sector with no transition traction yet could offer, I investigated the barriers to transformative innovation diffusion in this sector and how they could be addressed.

In my research, I combined the field of wine with transition and circularity literature to gain insight into the barriers to transformative innovation in this sector and on how those might be overcome in a circular context. I selected France as my geographical scope, as one of the largest and strongest wine markets, still operating on linear practices. To reveal strategies for emerging from the linear lock-in in the French wine sector, I applied the Circular Decision-Making Tree (CDMT) to investigate what new strategies might result from the application of a circular decision-making logics exercise in a sector with no transition traction yet. Through this exercise, four groups of outcomes resulted:

- First, insight on potential sustainable innovation reprioritizations favoring those that intervene earlier in the life cycle of wine,
- Second, eight barriers that may act as obstacles to engaging with and accelerating the desired transition, and
- Third, eight potential facilitators of circular economy in this sector addressing the barriers named and encouraging future diffusion of circular practices in wine production.
- Overall, an exploration of how the CDMT might be applied in the French wine sector to help navigate the uncertainty in the transition to a circular economy.

I expect some of the barriers to circular wine identified in Chapter 6 might be potentially generalizable in other sectors and contexts, such as cultural entrenchment in deep path dependencies, optimizations substituting for transformative innovation, and pitfalls resulting from the WRP. Similarly, strategies identified include incentivizing

transformative practices financially, reducing producer-consumer fragmentation, and integrating synergistic strategy through the supply chain. However, these specific results are not the primary goal for the replicability of this research; rather, I propose that arming decision-makers with this reflexive exercise in applying circular decision-making logics may be suitable for replication in many contexts for identifying barriers and potential strategies for addressing barriers.

I found that the transition to a circular economy in the French wine sector is likely not transforming because there is a lack of transformative action in regime organizations; applying the practices observed in Chapter 3 may increase the potential for uptake of circular niches in this field as well. Based on this, I recommend that future researchers on this topic link this research with the principles for connecting niche innovation with regime institutions in Chapter 3. To translate the impact of these ideas measurably on the transition to circularity in the wine sector, I recommended implementing these options and evaluating and monitoring the effect on: market and business impact, social reception, future possibilities, value chain/supplier contracts, logistics, the success or pitfalls of the innovation selection and diffusion, and further, to reflect on future improvements based on the lessons learned, e.g., in product design, packaging, bottling, or wine production processes. Based on my results, I called for more explicit regulations on a regional, national, and international scale that truly fit with a circular paradigm, rather than recycling-oriented policies that will have to be phased out later. The innovations and strategies identified, among many others, illustrate that the technological part of this socio-technical transition exists, but social/cultural, policy, and economic barriers remain obstacles to the transition to CE in the French wine sector. I discuss this further in my recommendations for future research in section 7.4. This was an application of circular decision-making logics to the case of the French wine sector, but based on the results, I hypothesize the CDMT could similarly be applied in other sectors to explore barriers and facilitators of CE in other contexts and strengthen circular decision-making.

7.3. KEY LESSONS FOR STRATEGIZING IN THE TRANSITION TO CE

In this thesis, I presented a block of insights in terms of how CE is now being supported and understood within the existing situation. A number of these insights emerging from my PhD overall relate to possible solutions for governance, agency, and strategy. Now, I zoom out and reflect on the results discussed in 7.2 in a synthesized way to offer a more general narrative and to elaborate on these empirical and theoretical contributions relating to the circularity transition progress and paradoxes, key lessons learned for governance and agency, and insights for strategizing and decision-making.

Lesson #1: Utilize and scale circular services to advance the CE transition.

My first paper is one of the few scientifically published papers in general to study a circular service and how it can be scaled up and diffused from a niche to a regime context in practice. Services in a CE are understudied, yet very important to develop and research, because these are actually small systems of interconnected products, processes, and businesses. A circular service is an advanced type of experimentation that more realistically tests what could be diffused, replicated, and scaled up in a true circular economy, because it involves an interconnected web of a constellation of actors and organizations – true to life of a real economic system. One promising way to scale up a circular service addressed in my research is to connect the niche-regime with the regime-niche in transition space, indicating a need for better understanding of the particular dynamics of transition when we talk about circular economy.

Lesson #2: Understand how the particular dynamics of the transition in CE may manifest in practice.

The WRP is one example of what might happen in the "chaos" stage of a transition, a casual understanding of which might bring to mind scenarios from extreme disorganization to anarchy. My research showed how it is a period of instability between regimes and how this might play out in practice, and that it should be carefully considered – understanding that this is a critical phase in which we should pay special attention that we are accelerating desired innovations in the vulnerable transition zone with increased potential for scaling up. In the transition zone between a linear and circular economy, it is possible that multiple actors or forces involved in practice have opposing labels simultaneously. Understanding that the "waste" or "resource" label is completely subjective – and can even differ between legal or actor viewpoints in the same time and space – enables better understanding of a contrasting assertion in business and negotiations, potentially improving conflict management in contract and business negotiations. The Waste-Resource Paradox concept raises questions about what is actually a waste, and how actors consider a waste versus a resource. Further, it uncovers in advance a variety of challenges for business and practice, which may better equip actors to deal with these challenges more proactively and effectively. Because CE and other sustainability strategies form policies around wastes and resources differently, this concept highlights how the same materials can be handled fundamentally differently: as waste, or as byproducts with economic value.

Lesson #3: Increase focus on an integrated approach to CE.

CE takes a social, environmental, and economic triple-bottom line approach, mirroring the sustainable development pillars. Its goal is to have a socially just, thriving economy that extracts the least possible virgin materials from the earth. While closing loops is one component of this, this should be the option when no higher-quality circularity improvements are possible. At a more serious tipping point where an unnecessary waste starts to become valorized, two threats to CE are created: a new or elevated market barrier for sustainable entrepreneurs who rely on waste at no or a low cost to them as an integral part of their business model; and a demand for waste production, rather than designing it out of the system: a core goal of CE. These integrated repercussions imply a need to also take an integrated approach to addressing CE. It is not always possible to avoid waste production, in which closing loops can be advantageous, but the possibility of a better solution must be considered first. In my research, I propose that an increased understanding in policy, business, and society that an innovation does not fully contribute to a true circular economy if the amount of extraction, production, and consumption levels remain the same has the potential to increase transformative decision-making.

Lesson #4: Include transformative changes in the economic and institutional environment.

Circular economy goes beyond resource efficiency. It affects institutional and economic institutions, and vice versa. Within an institutional context, linearity is still generally the most efficient, practical, and affordable path of least resistance. To realize a CE definitely includes transformative changes in the economic and institutional environment. Path dependencies are a characteristic of regime tendencies, but changes such as one example found in Chapter 3 of shorter contract durations – as also implemented as a strategy at the national ministry level – might offer the reduction of contractually obligated lock-in of current practices, potentially opening up more flexibility and potential for dynamism. In the context of ever-evolving technological innovations, a mutually beneficial and progressive contract could be regularly updated and re-negotiated to allow space for novel efficiency improvements to increase with time. Raising the WRP may empower policymakers and other actors to make transformative changes to better align short-term solutions with long-term visions, through e.g., stronger legal and financial incentives for innovations acknowledging potential rebound effects and WRP dynamics.

Lesson #5: Address the agency, roles, and capacities of decision-makers to support the CE transition.

To accelerate the transition to a circular economy, we are in need of particular types of agency. My research addressed and described an underlying transformative capacity within the regime. The CE transition in practice has often been translated into closing resource loops, and mostly found at practice level where circular objects and interventions are taking place. I have already argued that approaching a transition implies the need for systemic changes; these changes eventually take place at the regime level for a transition to happen. Actors from within institutional settings creating transformative change and supporting new practices can help in destabilizing the current regime, and my research underlines the transformative capacity and space for uptake of these innovations within the regime. I refer to this in my first paper; it is called the regime-niche. Actors relating to this dynamic have also been described as "hybrid regime actors" (Proka, 2021) and "proactive incumbents" (Hengelaar, 2017) in the literature as playing an important role in transitions, supporting my argument. These unique actors and organizations stepping outside their normative roles can both help to destabilize linear economic practices as well as create institutional space for uptake of transformative ideas and solutions in incumbent structures.

Lesson #6: Create contexts and conditions to deal proactively with paradoxes in the CE transition.

As I have described in section 7.1, the circular economy transition is full of paradoxes and dilemmas. Yet, there are ways to create the contexts and conditions to deal proactively with these paradoxes. For example, I learned through examples in my research that "winners" and "losers" in a transition process can be mitigated through lateral moves. For example, the Rijkswaterstaat transitioning to circular furniture might have caused thousands of furniture builders to lose their jobs; all of these workers were offered a retraining for how to rather repair furniture, so they could keep employment, but in a new way congruent with a paradigm shift to a CE. Similar strategies can be implemented in other sectors to reduce apprehension about and losses from radical transformation, reducing the strength of arguments about, e.g., job losses resulting from a transition. Contract considerations tie in with the "learning" described in Chapter 3 as one of the four categories of principles of connecting niche and regime elements to accelerate the transition to a circular economy. Despite a potential desire for change or improvement, linear practices may be contractually embedded in waste management systems. Learning curves and more radical innovations are systematically excluded through long-term binding contracts, with e.g., cite waste management facilities; shorter

or more flexible contracts could allow for adaptability and inclusion of new or higher-quality circular innovations.

Lesson #7: Take a critical approach to the acceleration of circular innovations.

My research encourages a discerning approach to innovation diffusion and issues cautionary advice against the uptake of all "circular" innovation. While there is literature on the rebound effect – when the environmental benefits created by an innovation are mitigated or outweighed by secondary effects (Zink & Geyer 2017) – this refers mostly to when efficiency gains, e.g., in terms of reduced environmental impact, are lost because of an increase in demand for and use of the respective product or material. The WRP takes this a step further and applies the idea in another sense. The risk considered in the WRP is not a loss in efficiency gains, but rather: a deeper entrenchment of current linear practices and, crucially, the danger of creating a demand for waste – encouraging and even valorizing waste production (which in many cases might otherwise be designed out further upstream). It is important to discern between the potentially transformative circular innovations that fit within a true circular future, versus those that are optimizing and reinforcing linear economy path dependencies. In my research, I argued for a systems approach and life cycle understanding: "circular innovations" that base a business model on the consumption of waste are not fully contributing to a circular economy unless they align with the core of circular economy: material extraction and consumption reduction, highest value preservation, and social justice.

Lesson #8: Drastically reduce optimizations of linear economy in favor of more transformative solutions and strategies.

Based on my research, I argue that circular initiatives need a herding for improved direction towards the transition to a CE. This could align visions and increase the likelihood that innovations will have a greater cumulative impact that creates long-term change, rather than sporadic and often disconnected efforts with potentially differing ideas about what a circular economy is – that may not build on each other, not grow, and therefore may fail to create impact in the transition to a CE. I encourage new (and current) business owners and innovators to orient their creative development towards process innovation over repurposing waste and to be strategic, explorative, and self-reflective about the long-term impact of their business in different lifespan and growth scale scenarios, and furthermore, to consider externalized (material, energy, economic, and social) costs and repercussions. In this way, actors can better address the root problem of linearity, rather than its symptoms. Similarly, circularity potential may be increased by applying funding proportional to the transformative nature of an

innovation, rather than the commonly used evaluation criteria of how eye-catching it is to the public.

Lesson #9: Utilize a new type of circular decision-making logic in governance strategies that challenges current assumptions.

In my dissertation, I posited that we need a new decision-making logic to change the assumptions on which we operate business and policy, because decision-making based on underlying assumptions of the current linear regime are highly likely to lead to optimization. The circular decision-making logic I described encourages a critical examination of an innovation that closes a material or product loop. Some innovations may at first seem circular when considering them in the current linear economy context, but do not fit within the context of a regenerative circular paradigm where waste is designed out. This is important for all circular decision-makers to consider, in order to prevent an unintentional and undesired reversion to an enhanced lock-in of linear economy (under the guise of circularity). Applying this perspective can enable decision-makers, policymakers, and researchers to think in a systems sense and consider potentially overlooked traps of circular innovations that may contribute positively to one of the missions of CE but at the cost of another. I argue that decision-makers should strategize to destabilize and break down: wrong incentives, highlighted by the WRP perspective; linear cultures, structures, practices, and path dependencies as exemplified by the French wine sector; and a lack of critical approach to circular innovation, which the CDMT may assist in navigating.

Lesson #10: Emphasize systems thinking and reflexivity in governance, to avoid externalizing negative environmental impacts and/or burden shifting.

I highlight the necessity to be cautious when navigating tradeoffs in decisions. In catering and similar food systems contexts, a reduction of plastic in logistics and packaging may come at a cost of an increase in food waste. Similarly, a reduction of plastic waste by turning it into something usable may come at the cost of increased energy use. Decision-makers must consider the whole system and entire life cycle of a product to ensure that a seemingly circular innovation is not simply shifting the environmental burden from the end-of-life phase to the manufacturing phase. The WRP enables decision-makers to be cognizant of the interdependencies and indirect effects of innovations in a globalized context. Because of the possibility for externalizing negative environmental impacts and the risk of burden shifting in creating circular innovations, I emphasize that a systems approach be taken to appreciate the full picture of a circular economy. I have advocated for actors and organizations to better approach

the transition to the circular economy as a true paradigm shift – not thinking from a linear starting point and thinking that we can "chip away" at unsustainable practices until we achieve a circular economy. A practice of reflexive governance can also help avoid creating continued, intentional overproduction (such as that seen in QMilk, from Chapter 4) to begin to diverge from path dependencies. As related to Lesson #4, decision-makers regularly reflecting on the short-term efficiency gains aligning with the long-term vision of circularity can help facilitate the implementation of transformative changes in the economic and institutional environment.

In this section, I have synthesized the results of my dissertation into lessons for strategizing and governance about: an integrated approach to CE, more attention to different types of agency and different roles, creation of specific conditions for favorable environments for the development and diffusion of CE practices, and ways for addressing paradoxes and pitfalls in the transition. Based on my results, I call for changes in systems and in underlying assumptions and starting points based on which the future vision is built, and I offer insights for decision-making within a circular context. In the following section 7.4, I will recommend research directions to develop based on these lessons, as well as in relation to the paradoxes addressed in 7.1.

7.4. FUTURE RESEARCH DIRECTIONS AND AGENDA

Much work has been done in transition research in the past few decades, and more recently, CE has become increasingly addressed in research as well. In this thesis, I explored and unpacked some of these uncertainties and paradoxes. My PhD research offers one set of novel insights, both conceptually and empirically, to CE and transitions research – which has also brought up further questions for future research. Still, many questions, tensions, and uncertainties remain open. In this section, I offer my recommendations for a future research agenda, relating to some of the limitations described in Chapter 3-6, and building on my work.

First, I recommend studying how better to scale up circular services. In this thesis, I studied a case of circular catering effectively being taken up at a regime organization level – but many other industries and services need observing for how they may be designed circularly, in an interconnected way at an experimentation level and how to increase their likelihood, once strong enough, of diffusing and being taken up at a regime level. While the majority of empirical research on circular economy focuses on production and manufacturing (which is also valuable), studying these products in isolation of other elements of the system in which they are to become embedded raises more questions as to if and how they will be embedded. An interesting extension of

my work would be to test the 15 principles for connecting alternative practices with incumbent organizations in the case of circular catering with other (existing or novel) circular services: either analyzing retrospectively or testing the principles when trying to accelerate a new service, and in other geopolitical contexts and in different sectors or with different services than the circular catering case examined. For example, size and ambition of a tender to adopt a radical innovation would likely be key in another sector as well. Additionally, I hypothesize that awareness-raising, testing spaces, common goal-oriented agreements, co-creation, university partnerships, and connecting platforms could also be tools for scaling CE through circular startups in sectors outside of catering, which would be interesting for future researchers to study and compare additional similar cases.

I recommend future researchers to apply post hoc analyses of historical cases of the WRP, which could offer predictive insight and/or warning signals of a WRP manifestation likely to occur. Economists and behavioral scientists may build on my research in this way for offer deeper insight into group and individual decision-making, and to understand: how was a price assigned to, or negotiated around, a formerly non-commodified waste? This could add an economic understanding of the WRP, which I have addressed in qualitative way due to lack of access to quantitative data. Similarly, economics researchers may be interested in expanding the CDMT to a sector-specific adaptation. A common present critical reflection concerned economic influences currently not being present in the tool, because all decisions in reality are embedded in market and socio-economic contexts that deal with tradeoffs and challenges. Decisions on waste inefficiencies and material considerations are in some ways embedded in cost-benefit tradeoffs, and this should be further addressed in later research related to the circular decision logics.

In a similar vein, I recommend the development of sector-adapted versions of the CDMT: a version of the original, more general CDMT adapted for use catering to a specific field, e.g., economic cost/benefit, social justice, social impacts, or environmental impacts such as CO_2 emissions or biodiversity. In this way, multiple versions of the tree specific to different secondary criteria could be developed, while keeping the first version of the CDMT in this paper as the original frame of reference. Secondly, I recommend leaning into more applied research and testing the tool in further workplaces, policy, and industry contexts to assess its impact on circular decisions in practice. Verifying the CDMT in practice could help understand what barriers there might be during implementation. For example, I recommend the tree be taken up by power researchers to study and potentially embed the influence of regulatory patterns on waste treatment or power dynamics – that affect decisions and impact the ability of an actor to exercise

autonomy and executive power – to begin using such a novel circular decision-making logic. I also recommend including an analysis of which types of actors and organizations might adopt the logics of the CDMT, and which of their attributes are related to this openness to innovation. Similarly, we might study how to increase social acceptance to address the human aspect of advancing the transition to a circular economy, e.g., in the wine sector.

Extending study on these circular decision logics, a related research recommendation is to improve industrial design through research and support design for disassembly. To offer a mathematical way to answer questions of diffusion present in the same logic, I encourage future researchers to build on this presentation of the CDMT through agent-based modelling, social modelling on actors' behaviors and preferences, and factoring economic consequences and market considerations into this first tool offered here. Pairing this with agent-based modeling could offer a quantitative analysis of the connecting power of the practices for connecting niche and regime elements, and of the diffusion potential integrated into the circular logics to better inform decisions.

More direct field work, for example in France, could test and measure the outcomes of my research results in Chapter 6 empirically. Quantitative data was unavailable to us, despite searching databases and contacting practitioners in this field. This, as well as pairing with studies on energy aspects would be meaningful additions to my work. Energy is a relevant component of the (transition to a) CE, but was not a primary focus of my PhD, because of another field of researchers already addressing the energy transition specifically. For example, the findings on circularity in the French wine sector presented in this paper could be paired with work on drivers and barriers of renewable energy prosumerism in other Mediterranean wine regions, coupling my research mostly related to materials with other research mostly related to energy; together, this would capture a fuller picture of sustainability drivers and barriers in Mediterranean viticulture sustainability practices.

Future research should dive more deeply into the connection between CE and the FEW nexus, e.g., Valencia et al. (2022) and Parsa et al. (2021), and how these concepts and respective tools may complement each other. For example, food inherently takes both water and energy to make, and the CDMT was designed to consider the embedded waste streams contained within other waste flows. The WRP brings this to light and can be an interesting/appropriate lens through which to study the FEW nexus. Then we can also start to investigate such questions as: What percent of circular innovations are optimizations of linear economy, and how do we deal with these? Phase out? How? Leave for the time being for incremental gains? For how long then?

Zooming out, I also identify a number of issues that I encountered in my research, but did not focus on, to be explored further. For example, I recommend more research on organizational change. From my dissertation, I found that it can be difficult for organizations to adapt to or contribute to a transition, generally being path dependent. This is related to dynamics and unknowns surrounding organizational cultures and structures: the root(s) of their path dependencies are often implicit and/or unknown. For this reason, I recommend research on social studies related to e.g., industrial-organizational psychology, as well as research around the finance and power issues inherent to businesses and their organizational and economic structures. Part of the lock-in to linear economy can be traced to profits made in linearity, so I encourage researchers to study the systems put in power by and loyal to linear practices.

Research on developing transformative capacities and potential for navigating transition space transformative capacities within the regime should be explored further; there is a need for transformative capacity at the level of the regime, and creating such a space needs strategy and creates challenges. The challenge for policy and business is to start investing in that capacity and investing in that space; the challenge for research is to support decision-makers in the policy and business contexts with their challenges, consider the capacities needed, and think about which actors are supported in a CE. I recommend further developing the regime-niche, what its implications are, how to nurture it, how to help create it within organizations, and what kind of capacities are needed to navigate transition space.

Finally, I recommend more work combining industrial ecology and transformative governance capacities. Researching and creating systems to improve the traceability of materials could help improve the accuracy of material and waste databases, which could in turn lead to interesting research on more tools or further frameworks for new governance logics, operations, and decision-making. If we consider the idea of a circular standardization or certification, an interesting research question could address what these new forms of certifications might look like and how to de-standardize existing linear practices and norms in parallel.

7.5. A VISION FOR THE CIRCULAR ECONOMY – WHAT IF THIS ALL WORKS?

It is clear from my PhD that to embark towards this future goal of a circular economy, we will experience many different paradoxes, political structures, and uncertain dynamics, so there is no clear recipe for getting from here to there. I offer a perspective and a set of tools for people to use to figure out their own future storyline, which will

require navigation, to start moving away from current linear systems towards truly circular futures. As my concluding remarks, here I paint a picture of what I believe we will experience if we ideally succeed in transitioning to a circular economy, developed according to my views and understandings of the nature of this transition. I describe this vision to give an idea of the magnitude of change to come, and to demonstrate the systemic nature of the road ahead.

In this vision for the future, we have radically reduced material uptake, created completely new infrastructures, created new jobs, and shifted thought patterns oriented towards added value measured in terms of the ability to retain material in consumption systems. This implies we have completely changed the economic and legal institutions within which production and consumption take place. Business and governments have phased out all linear optimizations that reinforced that regime, and greenwashing is called out and eliminated.

We have come to a common agreement as to what CE is, with specific, operationalized definitions used in government and business. A new, transparent certification for businesses, innovations, and policies to be labeled as "circular" has emerged, so the meaning of the word is not diluted, and everyone understands the specifics of a company or organization's practices if they are certified circular (comparable to "organic" or "Fair Trade"). The social standard for circular innovations has been raised, to only reward increasingly more transformative innovations. Product-service systems are integrated where appropriate and have demonstrated consumption-reducing potential.

Waste and consumption have become more traceable to the source; outsourcing of waste/wasteful processes and burden shifting has become transparent and drastically reduced. This has improved monitoring and evaluation processes, and it has created clearer insights and supported sharper observations in reflexive monitoring. Cities claiming to be circular – but that were transferring waste outside and thereby decreasing circularity of surrounding areas (to allow their own city to be more sustainable) – have become a thing of the past. Accountability for consumption sources has drastically improved, increasing accuracy in record-keeping and statistical databases (e.g., systemic or frequent border-crossing to consume the same goods at a cheaper price is traced to the original consumer and their current place of residence – not only considering the context in which it is consumed).

Cities are all models for circularity, so that it is no longer novel and exciting, but the non-radical norm and new standard of business and operations. Urban planning creates space for eco-industrial parks and industrial symbioses for unavoidable wastes. For

example, city planners and other gatekeepers designate physical spaces that allow for direct material and energy exchange, due to proximity and forethought, designing in space an industrial company in place to have a physical space for a balancing counterpart to move in and create a synergy. Circular decision-making logics have been critically applied to vet that the production of that waste could not have been avoided, designed out, or reduced its environmental impact.

Governments are no longer actively or passively obstructing CE progress, and there is a common agreement in society that climate change and linear practices contributing to it are imminent threats, a problem to be solved collectively, and can only be dealt with in global collaborations – and that circularity is one appropriate strategy for targeting this. The Global South learned from observing demonstrated resource, production, and consumption inefficiencies in the Global North and leapfrogged over many optimizations of LE directly to true circular practices.

Lastly, people are maintaining a healthy criticism of CE once it is in place. This is because circularity – while a dramatic improvement over the previous linear practices and a major step forward for society – is still not a bulletproof solution; in this circular future, people continue to seek out and develop radical and transformative innovations to further improve the newly incumbent practices. Having transitioned to a circular economy, we may not know what will come next (and in an undesirable case-scenario, there is risk of another societal shift oscillating back to linear practices), but with increasing public support for sustainable practices as well as increasing knowledge in and support for sustainability transitions, I hope and expect that a regime shift to CE is one huge step in the longer journey to continuously increasing sustainability on Earth.

7.6. REFERENCES

Circularity Gap Report. (2021). Circle Economy. Accessed on 21 December 2021 from https://www.greengrowthknowledge.org/research/circularity-gap-report-2021

Hengelaar, G. (2017). *The Proactive Incumbent: Holy grail or hidden gem?: Investigating whether the Dutch electricity sector can overcome the incumbent's curse and lead the sustainability transition* (No. EPS-2016-ERIM Series 438-ORG).

McCandless, J. (23 November, 2021). Accessed on 10 December 2021, from https://www.newsweek.com/toyota-prius-biggest-catalytic-converter-theft-target-us-1650471

Parsa, A., Van De Wiel, M. J., & Schmutz, U. (2021). Intersection, interrelation or interdependence? The relationship between circular economy and nexus approach. *Journal of Cleaner Production*, 127794.

Proka, A. (2021). Organising for power change: Transformative Business Models for the Energy Transition.

Smith, A. (2007). Translating sustainabilities between green niches and socio-technical regimes. *Technology analysis & strategic management, 19*(4), 427-450.

Valencia, A., Zhang, W., & Chang, N. B. (2022). Sustainability transitions of urban food-energy-water-waste infrastructure: A living laboratory approach for circular economy. *Resources, Conservation and Recycling*, *177*, 105991.

Zink, T., & Geyer, R. (2017). Circular economy rebound. *Journal of Industrial Ecology*, *21*(3), 593-602.

SUMMARY & SAMENVATTING

SUMMARY

In current business and practice, there is a reigning linear economy in our society's manner of dealing with resources – operating on a "take-make-waste" production and consumption paradigm. In light of increasing strain on natural resources – related to increasing global consumption and waste – and mounting environmental threats, it is argued that transformative change is necessary to protect the earth's natural resources, upon which human life depends. What is needed is a fundamental, structural, and systemic change to production and consumption patterns: a transition to a circular economy (CE).

The field of transition research studies the dynamics of complex societal problems and guides the development of systems solutions to address these problems. Accordingly, I applied transition theory as the main lens to my research with the aim of uncovering new insights in circular economy (Chapter 1). In this thesis, I identify specific characteristics and challenges relating to the physical reality of CE transition. Taking a physical-material and conceptual-theoretical starting point, I describe crucial paradoxes that have not previously been identified and that have important implications for governance approaches in the transition to CE. I address if the current circular policies and initiatives are truly transformative in nature, and I investigate what tools would be beneficial to accelerating this transition. Further, I explore what governance and decision-making may be necessary to empower and facilitate a true transition to a circular economy. In seeking to address current knowledge gaps, the main research question of this thesis was:

What are the key dynamics in the transition to a circular economy, and what does that imply for strategy and governance?

I took a primarily pragmatic research approach, which generally uses innovative, best-fit methodological approaches to elicit results that inform practice and action. In accordance with the principles of this scientific philosophy, my motivation was to increase analytical knowledge while also creating frameworks and understandings that could be applicable in real-world settings. This informed the methodology selected for my thesis: a multiple methods approach combining literature reviews, interviews, empirical observations, international workshops, and conceptual innovation work (Chapter 2). The major content sections of the thesis begin by describing 15 principles for connecting niche innovation with incumbent practice observed through empirical work, directly studying a case of upscaling (Chapter 3). Then, I identify a noteworthy paradox that emerges in the transition to a circular economy and discuss four key

related practical dilemmas resulting in implications for CE (Chapter 4). In response, I offer in the following chapter a promising tool for navigating circular decisions, as related to the aforementioned paradox, based on a different logics system (Chapter 5). Lastly, I apply this newly developed decision-making framework as a tool to explore the state of transition to CE, barriers thereof, and potential facilitators of CE a particular context and sector (Chapter 6). The chapters consist of two articles published in a peer-reviewed high-impact journal, one article accepted for publication with revisions, and one chapter applying learnings from these papers (to be submitted for publication). Below, I summarize the most important insights and contributions from each of these chapters:

Empirical contribution: Mechanisms for bridging the gap between the niche and regime, in the diffusion of a circular service.

I begin my thesis research by studying the unique phenomenon of a circular service being scaled up from a niche to a regime level through a network of circular startups. By regime, I refer to society's current dominant cultures, structures, and practices; by niche, I refer to small-scale, rising innovative business models and thought patterns created as alternatives to the current regime. I describe from empirical observations a specific case in which there emerged a live, physical proof-of-concept on how waste and resource flows could be connected between businesses to form a circular catering model. Observing this in real time provided insight into how to create settings that potentially can increase the ability to foster the creation of and scaling up of circular services in other sectors and industries, and, more generally, how to help to facilitate a more widespread reach for the acceleration of the transition to a circular economy. Through an abductive analysis of this case, I offer empirical contributions by categorically coding interview results and describing the resulting drivers for circular innovation uptake and diffusion at a service level, and I summarize these into 15 observed principles for connecting and integrating niche innovations to incumbent practice. These principles include market pressure and peer competition, meeting the growing demand for sustainable alternatives and products, mandates from higher-level institutions, upholding international treaties, entering climate agreements, contracts negotiated to financially or socially incentivize sustainable alternatives, (inter) national competitions, and a platform for communication that engaged emerging niche innovations with regime organizations.

Identifying these practices and principles that prime the setting for niche and regime elements to connect offered a basis for direction to both of these elements on how to gain exposure to and connect with their counterpart in a mutually beneficial way.

The fifteen principles for connecting niche ideas with regime institutions described in my research may enable companies, organizations, governments, universities, entrepreneurs, and other actors and institutions to increase activities related to these principles that encourage empowerment of niche ideas and simultaneously engage regime elements. This case also teaches a lesson about responsible governance and power: the highest governing body of the Netherlands (i.e., the Rijksoverheid, in this case study) was aligned with and effectuated actions that contributed to the Dutch national goal of being fully circular by 2050, which was an important and effective catalyst in the uptake and scaling of a circular service to a national scale. The 15 principles identified may also be of global relevance, as the results indicate that they also may facilitate the furthering of a transition in another industrial, cultural, or political context.

Conceptual contribution: Dilemmas and implications of the Waste-Resource Paradox

Many new innovations, business models, and policies have begun to emerge to support the push for further institutionalizing CE practices. During my empirical work, I observed that a large portion of these attempts are based on transforming a flow currently labeled as a waste stream into a material input, i.e., a resource. I describe this as the Waste-Resource Paradox (WRP) – the phenomenon that a certain material at any time could be considered a waste or a resource, depending on the perspective of the handlers, the practicality of its use at the end of life, the cultural and geographical context surrounding it, and the legal backdrop against which it is evaluated. It is further paradoxical because the innovations related to the WRP are generally designed to reduce waste and advance the transition to a circular economy. However, they ironically increase the risk of creating a demand for these waste streams, which can tighten a lock-in of the current linear economy regime. I observe in my research how this manifests in practice to create various sustainability dilemmas:

- **Material:** Instead of disincentivizing overproduction through waste processing fees or other regulatory measures, closing a loop may create a steady demand for unnecessary waste – potentially creating a rebound effect and causing more material to be wasted in the long term.
- **Energy:** Innovating to reduce material waste may result in a negative tradeoff by increasing energy waste. For example, converting plastic waste into pellets to use as filaments for 3D printers diverts material from landfills but causes a new demand for higher energy consumption.
- **Economic:** "Circular" business models often have a waste stream as a critical input, and may assume free access to this waste. If demand for this waste is increased, a

price for this waste (resource) may be assigned: waste-producing companies could then profit from their waste production, while a new barrier to the market would be created for entrepreneurs.
- **Social:** Recycling waste electronics may reduce the extraction of virgin critical and rare earth metals, but toxic residues from manually breaking down this waste – which often occurs under unsafe conditions – can create severe respiratory and reproductive health problems and damaged ecosystems in the areas surrounding these informal recycling centers (typically in the Global South). This highlights the social injustices of current practices related to the WRP.

Circular business models or policies based on the WRP may thus result in being counter-productive to CE by catalyzing a rebound effect of material use, creating a tradeoff with increased energy use, bankrupting circular startups, and posing a risk to human health and the ecosystem. Unpacking the dynamics of the WRP creates awareness of the risks and tradeoffs when building novel business models that use waste as a commodity, and of the implications this has in the transition to a sustainable, just circular economy. Furthermore, it offers a widened decision-making capacity for policymakers, investors, and business owners to consider the long-term impact of innovations with circular intents in the transition zone between a linear and a circular economy.

Conceptual contribution: A framework for navigating decisions in circular economy – the Circular Decision-Making Tree

Despite increasing efforts aimed at becoming more circular, society is still in a linear economy regime. Often, we see attempts at circular decision-making taking the existing economy as the starting point and working to incrementally improve upon that. Yet, navigating transitions requires envisioning a whole new system as the basis for decisions – one that is not predicated on assumptions of and incremental adaptations to the current paradigm. In response to this practical issue, I offer a new decision-making logic with the aim to support actors in government and business to more effectively translate circularity visions into initiatives with meaningful impact. This distinct logic forms the backbone of the Circular Decision-Making Tree (CDMT) – a decision-making framework that I have operationalized to support actors and organizations in considering the quality of an innovation or policy with respect to circularity and diffusion potential. The CDMT is organized into operational, strategic, and reflexive columns, and within it, includes complementary tools at decision points outside the main scope of the framework. These external tools include a life cycle assessment for an environmental assessment and a cost-benefit analysis for an economic assessment, but it is not a substitute for such tools. The main contribution of this new decision-making logic is that

it challenges the assumptions that are commonly made in the current linear economy context, an important step to shifting away from the linear economy paradigm.

The CDMT has been tested in focus group workshops in several countries and different contexts, which supported the hypothesis about a more general appetite for new instruments and approaches. The results of my research indicate that the CDMT contributes to science as a conceptual framework, and it contributes to practice as a tool for the improved mapping of decisions and for collaborative orientation when decision-making involves multiple actors. Decisions made in practice will always be embedded in a political and market context, which means that other variables may influence or trump circularity concerns. Actors often cannot exercise control over these external factors, but the CDMT equips them with a tool for obtaining new knowledge and devising strategies for moving forward in circular decisions.

Conceptual contribution: Explorative application of the conceptual innovations

To illustrate how the CDMT may be used in a specific context, I applied the CDMT to the French wine sector, which offered insight into the barriers to transformative innovation that exist in this sector and how these might be overcome. This application demonstrated the benefits and limitations of this framework and clarified the role that decision-making plays in the transition to CE. Specifically, it shed light on the potential usefulness of the CDMT as a practical tool in circular economy and identified relevant barriers and corresponding facilitators to CE in the French wine sector. I found that strengths of the CDMT include offering directionality in decisions, providing guidance to identify relevant questions at appropriate times, and helping to recognize drivers and barriers in general and in a particular sector.

When applying the CDMT, the "most circular" options are considered first, particularly before making a monetized demand for waste – which in many cases need not exist in the first place. In this manner, the framework helps avoid linear optimizations that would reinforce the current economic regime (relating to the previously described Waste-Resource Paradox). As a conceptual contribution, the CDMT could also serve as a mapping, orientation, meta scheme, or communication tool for transparency within the organization itself, its supply chain, and its partnerships – fostering an understanding of common values and goals, which has potential to aid in creating a clearer roadmap to a more circular future. Based on the illustration, I propose that supplying decision-makers with this CDMT exercise may be suitable for replication in many different contexts and can be useful to practitioners and researchers in other sectors that also currently lack transformative practices, helping to identify barriers and potential solutions.

Synthesis: Key paradoxes and insights in the transition to CE

My thesis addresses various elements of circular entrepreneurship in both the niche and regime contexts. I critically examined circular business models and innovations that may involve traps and pitfalls that could paradoxically reinforce linear path dependencies, which would further support the strength and resistance of the current economic system and work against a circular future. Further, I explored the potential for increasing capacities for transformative governance within the transition to a circular economy and developed a new decision-making logic, which I applied in a currently linear sector to explore why the transition to CE is not advancing and to illustrate the CDMT process and flow. Throughout my PhD, it became clear to me that we are still in the early stages of the transition to a circular economy, despite the promising signs of circular experimentation, entrepreneurship, and research emerging in recent years. This may be in large part due to the inherent uncertainties and difficult dilemmas involved in transitioning from one economic system to another. In my research, I identified a number of paradoxes that emerge within the transition to a circular economy:

- ***Paradox #1:*** *Increasing circular initiatives, but decreasing overall circularity:* Increasing numbers of circular initiatives are forming; yet, we are paradoxically becoming increasingly less circular with time in recent years. The number and strength of circular initiatives are indeed growing, but perhaps overconsumption and production are growing alongside at an even stronger rate.
- ***Paradox #2:*** *Inherent tradeoffs between the sustainability pillars of circular economy:* Through attempts to progress in the transition to CE, there is sometimes a significant sacrifice made of a given element of sustainability (e.g., social justice) in favor of another (e.g., environmental sustainability). If the transition reduces material use, but it is not equitable across nations and generations, a true circular economy has not been achieved.
- ***Paradox #3:*** *Cross-scale circularity rebound effects:* While some cities may exhibit statistically exemplary levels of circularity, they may actually have a rebound effect and decrease global circularity if truly transformative systems and solutions are not in place. For example, such a rebound effect may be caused by outsourcing (and potentially increasing) unsustainable materials, processes, and practices to surrounding areas.
- ***Paradox #4:*** *Tradeoff between the potential for uptake and the potential for transformation:* More complex systems of innovations generally face more resistance than single products when breaking through to the regime. However, interconnected innovations are more likely to be transformative to a regime by including some of

the complexity of the real world, creating uncertainty about what type of innovation (system) has the highest potential circular impact.

- ***Paradox #5:*** *Some circular attempts increasing linear path dependencies:* Some innovations that aim to contribute to a circular economy inadvertently also provide incentives to continue operating linear processes that might otherwise be radically transformed. Consequently, they are paradoxically working against the very transition that they aim to accelerate.
- ***Paradox #6:*** *Acceleration potentially reducing the integrity of the innovation's radicalism:* Niche ideas and innovations experience protection by being shielded, nurtured, and empowered in their environment; when scaling up, they may break path dependencies, but they may also be assimilated within an unchanged regime, rendering their original radicalness tepid.
- ***Paradox #7:*** *Traditional transition dynamics displaying counter-intuitive behavior:* In a transition, niches come together to form clusters, creating their own regime – the very idea that they are, in principle, alternatives to. Reciprocally, there are proactive actors acting like niches within the incumbent regime context that begin to think progressively and independently.

From the seven paradoxes I identified as relevant in the transition to a circular economy, it became clear that strategizing in this context is highly uncertain and that pathways are frequently not straightforward. Yet, a number of insights also emerged as a result of my PhD, which may help in addressing these difficulties. Below, I have listed these insights as key lessons for strategizing and decision-making:

- ***Lesson #1:*** Utilize and scale circular services to advance the CE transition: One promising way to scale up a circular service is to connect the niche-regime with the regime-niche in the transition zone – indicating a need for increased understanding of these dynamics of the CE transition.
- ***Lesson #2:*** *Understand how the particular dynamics of the CE transition may manifest in practice:* The WRP is one example of what might happen in the "chaos" stage of a transition. This period of instability between regimes is a critical phase, in which we should ensure that we are supporting and accelerating particularly those innovations that fit within a true CE.
- ***Lesson #3:*** *Increase focus on an integrated approach to CE:* CE takes a social, environmental, and economic triple-bottom line approach, with the goal of a socially just, flourishing economy that extracts as few virgin materials from the earth as possible. Closing material loops may be a component of CE, but it should not come at the cost of a rebound or problematic tradeoff in one of the other pillars.

- **Lesson #4:** *Include transformative changes in the economic and institutional environment:* The transition to CE goes beyond resource efficiency – it has institutional and economic impacts, and vice versa. Within an institutional context, linearity is still generally the most efficient, practical, and affordable path of least resistance. Thus, realizing a CE definitely requires transformative changes in the economic and institutional environment.
- ***Lesson #5:*** *Address the agency, roles, and capacities of decision-makers in supporting the CE transition:* Actors from within institutional settings that create transformative change and support new practices can help to move away from the current regime, and there is a need for and capacity for this transformative space and action now observed at the regime level.
- ***Lesson #6:*** *Create suitable settings to deal proactively with paradoxes in the CE transition:* Strategies can be implemented to reduce apprehension about radical transformation, addressing concerns about, e.g., job losses resulting from a transition.
- ***Lesson #7:*** *Take a critical approach to the acceleration of circular innovations:* The risk related to the WRP is a deeper entrenchment in current linear practices and, crucially, creating a demand for waste. It is important to differentiate between innovations whose growth should be supported versus those that would counteract CE progress.
- ***Lesson #8:*** Drastically reduce optimization of a linear economy in favor of more transformative solutions and strategies: I encourage innovators to be strategic and self-reflective about their long-term impact in different lifespan and growth scale scenarios, and to consider externalized repercussions, such as material, energy, economic, and social costs. Such an approach encourages actors to address the root problem of linearity, rather than its symptoms.
- ***Lesson #9:*** *Utilize a new type of circular decision-making logic in governance strategies that challenges current assumptions:* I posit that we need a new decision-making logic to change the assumptions on which we operate business and policy, because decision-making that is based on underlying assumptions of the current linear regime is highly likely lead to optimization of a linear economy, instead of a shift to a circular economy.
- ***Lesson #10:*** *Emphasize systems thinking and reflexivity in governance, to avoid externalizing negative environmental impacts and/or burden shifting:* Decision-makers must consider the whole system and entire life cycle of a product to ensure that a seemingly circular innovation is not simply shifting the environmental burden to a different life cycle phase. Exploring the WRP enables decision-makers to be cognizant of the interdependencies and indirect effects of innovations in a globalized context.

In this dissertation, I synthesize the results of my research into lessons for strategizing and governance. These lessons concern developing an integrated approach to CE, extending more attention to different types of agency and different roles, creating specific conditions for a favorable environment for the development and diffusion of CE practices, and establishing ways to address paradoxes and pitfalls in the transition. Based on my results, I call for changes in existing systems and in the underlying assumptions on which our current vision for the future is built, and I offer insights into decision-making within a circular context. Finally, I propose an agenda for future research that builds on my work, and conclude with a description of my own vision of an actualized circular economy – what if it all works?

SAMENVATTING

De wijze waarop bedrijven en consumenten in hun dagelijkse doen en laten met grondstoffen omgaan, wordt gedomineerd door het principe van een lineaire economie, die gebaseerd is op een 'take-make-waste' productie- en consumptieparadigma. Er is een toenemende druk op natuurlijke grondstoffen, groeiende wereldwijde consumptie en afvalproductie en toenemende milieubedreigingen. Daarom betoogt men dat transformatieve verandering nodig is om de natuurlijke grondstoffen van de aarde, waarvan het menselijk leven afhankelijk is, te beschermen. Er is een fundamentele, structurele en systemische verandering van productie- en consumptiepatronen nodig: een transitie naar een circulaire economie (CE).

Het vakgebied van transitieonderzoek bestudeert de dynamiek van complexe maatschappelijke problemen en richt zich op de ontwikkeling van systeemoplossingen om deze problemen aan te pakken. Daarom heb ik de transitietheorie als de belangrijkste lens van mijn onderzoek toegepast, met als doel nieuwe inzichten in de circulaire economie te verkrijgen (Hoofdstuk 1). In dit proefschrift identificeer ik specifieke kenmerken en uitdagingen met betrekking tot de dagelijkse praktijk van de CE-transitie. Met een fysiek-materieel en conceptueel-theoretisch uitgangspunt, beschrijf ik cruciale paradoxen die niet eerder zijn geïdentificeerd en die belangrijke implicaties hebben voor governance-strategieën in de transitie naar CE. Ik ga in op de vraag of het huidige circulaire beleid en de huidige initiatieven werkelijk transformatief zijn, en ik onderzoek welke instrumenten nuttig kunnen zijn om deze transitie te versnellen. Verder onderzoek ik welk soort governance en besluitvorming nodig zijn om een transitie naar een echte circulaire economie mogelijk te maken en te faciliteren. Om de huidige kennislacunes aan te pakken, heb ik als centrale onderzoeksvraag van dit proefschrift geformuleerd:

Wat zijn de belangrijkste dynamieken in de transitie naar een circulaire economie, en wat betekent dat voor strategie en bestuur?

Ik koos voornamelijk voor een pragmatische onderzoeksaanpak, die innovatieve methodologische benaderingen gebruikt om resultaten te verkrijgen die de praktijk en interventies verder kunnen helpen. Geïnspireerd door deze wetenschappelijke filosofie, was mijn motivatie om analytische kennis te vergroten en tegelijkertijd kaders en inzichten te creëren die toepasbaar zouden kunnen zijn in de praktijk. Dit vormde de basis voor de methodologie die ik voor mijn proefschrift heb gekozen: een benadering met meerdere methoden die literatuuronderzoek, interviews, empirische observaties, internationale workshops en conceptueel innovatiewerk met elkaar combineerde

(Hoofdstuk 2). De belangrijkste inhoudelijke onderdelen van dit proefschrift beginnen met het beschrijven van 15 principes voor het verbinden van niche-innovaties met de gevestigde praktijk, gebaseerd op empirisch werk waarbij de opschaling van een innovatie rechtstreeks wordt bestudeerd (Hoofdstuk 3). Vervolgens identificeer ik een opmerkelijke paradox binnen de transitie naar een circulaire economie en bespreek ik vier gerelateerde praktische dilemma's die implicaties hebben voor CE (Hoofdstuk 4). Als reactie daarop bied ik in het volgende Hoofdstuk een veelbelovend hulpmiddel aan voor het navigeren van circulaire beslissingen – ook in verband met de bovengenoemde paradox (Hoofdstuk 5). Ten slotte pas ik dit nieuw ontwikkelde besluitvormingskader toe als een instrument om de staat van transitie naar CE, belemmeringen daarvoor en potentiële versnellers ervan in een bepaalde context en sector te verkennen (Hoofdstuk 6). De hoofdstukken bestaan uit twee artikelen die zijn gepubliceerd in een peer-reviewed tijdschrift met grote impact, één artikel dat is geaccepteerd voor publicatie met herzieningen, en één hoofdstuk dat de lessen uit deze artikelen toepast (in te dienen voor publicatie). Hieronder vat ik de belangrijkste inzichten en bijdragen uit elk van deze hoofdstukken samen:

Empirische bijdrage: Mechanismen voor het overbruggen van de afstand tussen de niche en het regime, in de diffusie van een circulaire dienst.

Ik begin mijn promotieonderzoek met een casestudy van een circulaire dienst die via een netwerk van circulaire startups wordt opgeschaald van een niche naar het regimeniveau. Met 'regime' verwijs ik naar de huidige dominante culturen, structuren en praktijken van de samenleving; met 'niche' verwijs ik naar de kleinschalige, opkomende innovatieve businessmodellen en denkpatronen die zijn ontwikkeld als alternatief voor het huidige regime. Ik beschrijf vanuit empirische observaties een specifiek geval waarin er een fysiek proof-of-concept naar voren kwam op welke wijze afval- en grondstofstromen tussen bedrijven kunnen worden verbonden om een circulair cateringmodel te vormen. Door dit in realtime te observeren, werd inzicht verkregen in hoe condities kunnen worden gecreëerd die in potentie het vermogen kunnen vergroten om de ontwikkeling en opschaling van circulaire diensten in andere sectoren en industrieën te bevorderen, en, meer in het algemeen, om te helpen bij het faciliteren van een breder bereik voor de versnelling van de transitie naar een circulaire economie. Door middel van een abductieve analyse van deze casus, bied ik empirische bijdragen door de interviewresultaten categorisch te coderen en de resulterende drivers voor de acceptatie en verspreiding van circulaire innovatie op serviceniveau te beschrijven. Ik vat deze samen in 15 waargenomen principes voor het verbinden en integreren van niche-innovaties met de gevestigde praktijk. Deze principes omvatten marktdruk en peer-concurrentie, het voldoen aan de groeiende vraag naar duurzame alternatieven en

producten, opdrachten van instellingen op hoger niveau, het naleven van internationale verdragen, het aangaan van klimaatovereenkomsten, contracten bedoeld om duurzame alternatieven financieel of sociaal te stimuleren, (inter)nationale competities, en een platform voor communicatie dat opkomende niche-innovaties met regime-organisaties samenbrengt.

Het identificeren van deze praktijken en principes die de basis vormen voor de verbinding van niche- en regime-elementen, bood een basis voor beide aspecten om bekendheid te genereren en verbinding te kunnen maken met hun tegenhanger. De vijftien principes voor het verbinden van niche-ideeën met regime-partijen die in mijn onderzoek zijn beschreven, kunnen bedrijven, organisaties, overheden, universiteiten, ondernemers en andere actoren en instellingen in staat stellen om activiteiten met betrekking tot deze principes te vergroten die de empowerment van niche-ideeën aanmoedigen en tegelijkertijd regime-elementen betrekken. Deze casus leert ons ook een les over verantwoord bestuur en macht: het hoogste bestuursorgaan van Nederland (de Rijksoverheid) voerde acties uit die bijdroegen aan het Nederlandse nationale doel voor CE voor 2050. Dit bleek een belangrijke en effectieve katalysator in de opname en opschaling van een circulaire dienst naar landelijke schaal. De 15 geïdentificeerde principes kunnen ook van mondiale relevantie zijn, aangezien de resultaten aangeven dat ze ook de bevordering van een transitie in een andere industriële, culturele of politieke context kunnen vergemakkelijken.

Conceptuele bijdrage: Dilemma's en implicaties van de Waste-Resource Paradox

Er zijn veel nieuwe innovaties, bedrijfsmodellen en beleid ontstaan ter ondersteuning van het streven naar verdere institutionalisering van CE-praktijken. Tijdens mijn empirisch werk merkte ik dat een groot deel van deze pogingen gebaseerd was op het transformeren van een materiaalstroom die momenteel wordt bestempeld als een afvalstroom, naar een materiële input, oftewel een grondstof. Ik noem dit de Afval-Grondstof Paradox [Waste-Resource Paradox (WRP)] – het fenomeen dat een bepaald materiaal op elk moment als een afvalstof of een grondstof kan worden beschouwd, afhankelijk van het perspectief van de afhandelaars, de bruikbaarheid van het materiaal aan het einde van zijn levensduur, de culturele en geografische context eromheen, en de juridische achtergrond waartegen het wordt beoordeeld. Het is verder paradoxaal omdat de innovaties met betrekking tot de WRP over het algemeen zijn ontworpen om afval te verminderen en de overgang naar een circulaire economie te bevorderen. Ze vergroten echter ironisch genoeg het risico dat er vraag naar deze afvalstromen ontstaat, wat de lock-in van het huidige lineaire economische regime

kan versterken. Ik observeer in mijn onderzoek hoe dit zich in de praktijk verschillende duurzaamheidsdilemma's creëert:

- **Materiaal:** In plaats van overproductie te ontmoedigen door middel van vergoedingen voor afvalverwerking of andere regelgevende maatregelen, kan het sluiten van een kringloop leiden tot een gestage vraag naar onnodig afval, waardoor er mogelijk een 'rebound-effect' ontstaat en op de lange termijn meer materiaal wordt verspild.
- **Energie:** Innoveren om materiaalverspilling te verminderen, kan leiden tot een negatieve afweging door een verhoogde energieverspilling. Door bijvoorbeeld plastic afval om te zetten in pellets om te gebruiken als filamenten voor 3D-printers, wordt materiaal van stortplaatsen afgevoerd, maar ontstaat er een nieuwe vraag naar een hoger energieverbruik.
- **Economisch:** 'Circulaire' businessmodellen hebben vaak een afvalstroom als essentiële input, en kunnen uitgaan van vrije toegang tot dit afval. Als de vraag ernaar toeneemt, kan een prijs aan dit afval (grondstof) worden toegekend: afvalproducerende bedrijven kunnen dan profiteren van hun afvalproductie, terwijl er een nieuwe belemmering op de markt wordt gecreëerd voor ondernemers.
- **Sociaal:** Het recyclen van afgedankte elektronica kan de winning van primaire zeldzame aardmetalen en zeldzame metalen verminderen, maar giftige residuen van het handmatig afbreken van dit afval – wat vaak onder onveilige omstandigheden gebeurt – kunnen leiden tot ernstige ademhalings- en reproductieve gezondheidsproblemen van de mensen die dit afval verwerken en tot beschadigde ecosystemen in de gebieden rondom deze informele recyclingcentra (meestal in arme landen). Dit benadrukt de sociale onrechtvaardigheden van de huidige praktijken met betrekking tot de WRP.

Circulaire bedrijfsmodellen of beleid gebaseerd op de WRP kunnen er dus toe leiden dat ze averechts werken voor CE door een rebound-effect van materiaalgebruik te katalyseren, een afweging te maken met een verhoogd energieverbruik, circulaire startups failliet te laten gaan en een risico te vormen voor de menselijke gezondheid en het ecosysteem. Door de dynamiek van de WRP uiteen te zetten, wordt men zich bewust van de risico's en afwegingen bij het ontwikkelen van nieuwe bedrijfsmodellen die afval als grondstof gebruiken, en van de implicaties die dit heeft voor de overgang naar een duurzame en rechtvaardige CE. Bovendien biedt deze aanpak beleidsmakers, investeerders en ondernemers een breder kader om na te denken over de langetermijneffecten van innovaties met circulaire bedoelingen in het overgangsgebied tussen een lineaire en een circulaire economie.

Conceptuele bijdrage: Een sturingsraamwerk voor beslissingen in de circulaire economie – De circulaire beslisboom [Circular Decision-Making Tree (CDMT)]

Ondanks toenemende inspanningen om meer circulair te worden, bevindt de samenleving zich nog steeds in een lineair economisch regime. Vaak worden er pogingen gedaan tot circulaire besluitvorming waarbij de bestaande economie als uitgangspunt wordt genomen en die dan daar stapsgewijs wordt aangepast. Maar om transities te navigeren, dient er een heel nieuw systeem te worden ontwikkeld als basis voor beslissingen – een systeem dat niet gebaseerd is op aannames van en stapsgewijze aanpassingen aan het huidige paradigma. Als antwoord op deze praktijkvraag bied ik een nieuwe besluitvormingslogica aan met als doel beslissers bij overheid en bedrijfsleven te ondersteunen om circulaire visies beter te vertalen naar zin- en impactvolle initiatieven. Deze onderscheidende logica vormt de ruggengraat van de circulaire beslisboom [Circular Decision-Making Tree (CDMT)] – een besluitvormingskader dat ik heb geoperationaliseerd om actoren en organisaties te ondersteunen bij het nadenken over de kwaliteit van een innovatie of beleid met betrekking tot circulariteit en diffusiepotentieel. De CDMT is georganiseerd in operationele, strategische en reflexieve kolommen. Hij bevat daarbinnen aanvullende instrumenten op beslissingspunten die buiten het hoofdbereik van het raamwerk vallen – bijvoorbeeld een levenscyclusanalyse voor een milieubeoordeling en een kosten-batenanalyse voor een economische beoordeling. De CDMT is geen vervanging voor deze instrumenten – de belangrijkste bijdrage van deze nieuwe besluitvormingslogica is dat hij de veronderstellingen die in de huidige lineaire economiecontext worden gemaakt, ter discussie stelt. Het gebruik van deze nieuwe circulaire besluitvormingslogica is een belangrijke stap om af te stappen van het paradigma van de lineaire economie.

De CDMT werd getest in focusgroep-workshops in verschillende landen en verschillende contexten, wat leidde tot een meer generiek behoefte aan nieuwe instrumenten en benaderingen. De resultaten van mijn onderzoek geven aan dat de CDMT bijdraagt aan de wetenschap als conceptueel raamwerk en aan de praktijk als een hulpmiddel om beslissingen beter in kaart te brengen – en voor collaboratieve verkenning wanneer er bij besluitvorming meerdere actoren betrokken zijn. Beslissingen die in de praktijk worden genomen, zullen altijd worden ingebed in een politieke en marktcontext, wat betekent dat andere variabelen de circulariteitsvraagstukken kunnen beïnvloeden of zelfs overtroeven. Actoren hebben vaak geen controle over deze externe factoren, maar de CDMT biedt ze een instrument om nieuwe kennis op te doen en strategieën te bedenken om vooruit te komen in circulaire beslissingen.

Conceptuele bijdrage: Verkennende toepassing van de conceptuele innovaties

Om te illustreren hoe de CDMT in een specifieke context kan worden gebruikt, heb ik de CDMT toegepast op de Franse wijnsector. De analyse/casus bood inzicht in de belemmeringen voor transformatieve innovaties die in deze sector bestaan en in de wijze waarop deze kunnen worden overwonnen. Deze toepassing toonde de voordelen en beperkingen van het raamwerk aan en verduidelijkte de rol die besluitvorming speelt in de overgang naar een circulaire economie. In het bijzonder werd het potentiële nut van de CDMT als praktisch instrument in de circulaire economie duidelijk en werden zowel belangrijke belemmeringen als bevorderende factoren voor CE in de Franse wijnsector geïdentificeerd. Ik ontdekte de sterke punten van de CDMT: het bieden van richting bij beslissingen, het helpen identificeren van relevante vragen op het juiste moment en het helpen herkennen van drivers en belemmeringen in het algemeen en in een bepaalde sector.

Bij het toepassen van de CDMT worden eerst de "meest circulaire" opties overwogen, vooral voordat er een gemonetariseerde vraag naar afval wordt gecreëerd – die in veel gevallen in de eerste plaats niet hoeft te bestaan. Op deze manier helpt het raamwerk lineaire optimalisaties te voorkomen die het huidige economische regime door de eerder beschreven Afval-Grondstof Paradox zouden versterken. Als conceptuele bijdrage kan de CDMT ook dienen als een mapping-, oriëntatie- en metaschema of communicatiemiddel voor transparantie binnen de organisatie zelf, haar toeleveringsketen en haar partnerschappen, waardoor een gedeeld begrip van gemeenschappelijke waarden en doelen wordt bevorderd. Dit kan helpen bij het creëren van een duidelijkere routekaart naar een meer circulaire toekomst. Op basis van de illustratie stel ik voor dat deze reflexieve CDMT-oefening met besluitvormers geschikt kan zijn voor toepassing in veel verschillende contexten en nuttig kan zijn voor professionals en onderzoekers in andere sectoren die momenteel geen transformatieve praktijken kennen, door belemmeringen en potentiële oplossingen te identificeren.

Synthese: Belangrijkste paradoxen en inzichten in de overgang naar CE

Mijn proefschrift behandelt verschillende elementen van circulair ondernemerschap in zowel niche- als regimecontexten. Ik heb kritisch gekeken naar circulaire businessmodellen en innovaties die valkuilen kunnen bevatten. Paradoxaal genoeg kunnen deze innovaties lineaire padafhankelijkheden zo versterken dat de kracht en weerstand van het huidige economische systeem verder wordt versterkt en een circulaire toekomst wordt tegengewerkt. Verder onderzocht ik het potentieel voor het vergroten van de capaciteit voor transformatief bestuur binnen de transitie naar

een circulaire economie en ontwikkelde ik een nieuwe besluitvormingslogica, die ik heb toegepast in een lineaire sector om te onderzoeken waarom de transitie naar CE niet vordert en om het CDMT-proces te illustreren. Tijdens mijn onderzoek werd het duidelijk dat we ons nog in de beginfase van de transitie naar een circulaire economie bevinden. Dit, ondanks alle veelbelovende tekenen van circulair experimenteren, ondernemerschap en onderzoek die de afgelopen jaren opkwamen. Dit is mogelijk voor een groot deel te wijten aan de inherente onzekerheden en lastige dilemma's die gepaard gaan met de transitie van het ene economische systeem naar het andere. In mijn onderzoek identificeerde ik een aantal paradoxen die naar voren komen binnen de transitie naar een circulaire economie:

- ***Paradox #1:*** *Toenemende circulaire initiatieven, maar afnemende algehele circulariteit:* Er ontstaan steeds meer circulaire initiatieven, maar paradoxaal genoeg wordt de maatschappij de laatste jaren steeds minder circulair. Het aantal en de kracht van circulaire initiatieven groeien wel, maar ik vermoed dat overconsumptie en productie nog sterker meegroeien.
- ***Paradox #2:*** *Inherente afwegingen tussen de duurzaamheidsaspecten van de circulaire economie:* Door pogingen om vooruitgang te boeken in de overgang naar CE, gaan soms sommige aspecten van duurzaamheid ten koste van andere (bijvoorbeeld ecologische rechtvaardigheid ten koste van sociale rechtvaardigheid). Als de transitie het materiaalgebruik vermindert, maar het is niet relatief rechtvaardig over landen en generaties verdeeld, is een echte circulaire economie niet bereikt.
- ***Paradox #3:*** *Cross-scale reboundeffecten van circulariteit:* Hoewel sommige steden statistisch gezien een hoge mate van circulariteit vertonen, kunnen ze echter de wereldwijde circulariteit verminderen als er geen echte transformerende systemen en oplossingen zijn. Een dergelijk reboundeffect kan bijvoorbeeld worden veroorzaakt door het uitbesteden (en mogelijk vergroten) van het gebruik van niet-duurzame materialen, processen en praktijken naar omliggende gebieden.
- ***Paradox #4:*** *Afweging tussen het potentieel voor opname en het potentieel voor transformatie:* Complexere systemen van innovaties ondervinden over het algemeen meer weerstand dan afzonderlijke producten bij het doorbreken van het regime. Onderling verbonden innovaties zullen echter eerder transformatief zijn voor een regime door een deel van de complexiteit van de echte wereld op te nemen, waardoor onzekerheid ontstaat over welk type innovatie(systeem) de hoogste potentiële circulaire impact heeft.
- ***Paradox #5:*** *Sommige circulaire pogingen versterken lineaire padafhankelijkheden:* Sommige innovaties die beogen bij te dragen aan een CE bieden onbedoeld steun aan huidige lineaire processen die anders radicaal zouden kunnen worden

getransformeerd. Hierdoor werken ze paradoxaal genoeg juist de transitie tegen die ze willen versnellen.

- ***Paradox #6:*** *Versnelling vermindert mogelijk de integriteit van het radicalisme van* de innovatie: Niche-ideeën en innovaties worden vaak afgeschermd, gekoesterd en bekrachtigd door en in hun omgeving; bij schaalvergroting kunnen ze padafhankelijkheden doorbreken, maar ze kunnen ook worden geassimileerd binnen een ongewijzigd regime, waardoor de oorspronkelijke radicaliteit wordt afgezwakt.
- ***Paradox #7:*** *Traditionele transitiedynamiek die contra-intuïtief gedrag vertoont:* In een transitie komen niches samen om clusters te vormen, waardoor hun eigen regime ontstaat – een systeem waar ze in principe juist alternatieven voor zijn. Omgekeerd zijn er proactieve actoren die optreden als kleine niches binnen de context van het zittende regime die progressief en onafhankelijk beginnen te denken.

Uit de zeven paradoxen die ik identificeerde als relevant voor de transitie naar een circulaire economie, werd het duidelijk dat strategievorming en besluitvorming in deze context hoogst onzeker is, met paden die vaak niet eenvoudig zijn. Toch kwamen er in mijn onderzoek ook een aantal inzichten naar voren die kunnen helpen bij het aanpakken van deze problemen. Hieronder heb ik deze inzichten opgesomd als belangrijke lessen voor strategie- en besluitvorming:

- ***Les #1:*** *Circulaire diensten gebruiken en opschalen om de CE-transitie te bevorderen:* Een veelbelovende manier om een circulaire dienst op te schalen is om het niche-regime te verbinden met de regime-niche in de transitiezone – wat wijst op een behoefte aan meer begrip van deze dynamiek van de CE-transitie.
- ***Les #2:*** *Begrijpen hoe de specifieke dynamiek van de CE-transitie zich in de praktijk kan uiten:* De WRP is een voorbeeld van wat er kan gebeuren in de 'chaos'-fase van een transitie. Deze periode van instabiliteit tussen regimes is een kritieke fase, waarin we ervoor moeten zorgen dat we alleen die innovaties ondersteunen en versnellen die passen binnen een echte CE.
- ***Les #3:*** *De focus vergroten op een integrale benadering van CE:* CE neemt een sociale, ecologische en economische triple-bottom line benadering als uitgangspunt en heeft als doel een sociaal rechtvaardige, bloeiende economie die zo min mogelijk nieuwe materialen uit de aarde haalt. Hoewel het sluiten van materiaalkringlopen een onderdeel van CE kan zijn, mag dit niet ten koste gaan van één van de andere pijlers.
- ***Les #4:*** *Transformatieve veranderingen opnemen in de economische en institutionele omgeving:* De CE-transitie betekent meer dan grondstoffenefficiëntie – CE heeft institutionele en economische gevolgen en andersom. Binnen een institutionele context is lineariteit over het algemeen nog steeds de meest efficiënte, praktische

en betaalbare weg van de minste weerstand. Het realiseren van een CE vereist dus zeker transformatieve veranderingen in de economische en institutionele omgeving.

- ***Les #5:*** *De slagvaardigheid, de rollen en de capaciteiten van besluitvormers aanspreken bij het ondersteunen van de CE-transitie:* Actoren vanuit een institutionele omgeving die transformatieve verandering creëren en nieuwe praktijken ondersteunen, kunnen helpen om weg te komen van het huidige regime. Er is een behoefte aan en capaciteit voor deze transformatieve ruimte en actie die nu op regimeniveau wordt waargenomen.
- ***Les #6:*** *Geschikte condities creëren om proactief om te gaan met paradoxen in de CE-transitie:* Strategieën kunnen worden geïmplementeerd om de weerstand tegen radicale transformatie te verminderen en zorgen over bijvoorbeeld banenverlies als gevolg van een transitie aan te pakken.
- ***Les #7:*** *Een kritische benadering nemen van de versnelling van circulaire innovaties:* Het risico met betrekking tot de WRP is een diepere verankering in de huidige lineaire praktijken en het creëren van een vraag naar afval. Het is belangrijk om onderscheid te maken tussen hoge-kwaliteit CE-innovaties en innovaties die de CE-vooruitgang zouden tegenwerken.
- ***Les #8:*** *De optimalisatie van een lineaire economie drastisch verminderen ten gunste van meer transformatieve oplossingen en strategieën:* Ik moedig innovators aan om strategisch en zelf-reflectief te zijn over hun langetermijnimpact in verschillende scenario's voor levensduur en groeischaal, en om externe gevolgen zoals materiaal-, energie-, economische en sociale kosten, in de overwegingen mee te nemen. Een dergelijke benadering moedigt actoren aan om het fundamentele probleem van lineariteit aan te pakken, in plaats van de symptomen ervan.
- ***Les #9:*** *Een nieuwe circulaire besluitvormingslogica gebruiken in sturingsstrategieën die de huidige aannames betwist:* Ik stelde dat we een nieuwe besluitvormingslogica nodig hebben om de aannames op basis waarvan we zakendoen en beleid voeren te veranderen. Besluitvorming gebaseerd op onderliggende aannames van het huidige lineaire regime leidt hoogstwaarschijnlijk tot de optimalisatie van een lineaire economie.
- ***Les #10:*** *Systeemdenken en reflexiviteit in governance benadrukken, om te voorkomen dat negatieve milieueffecten en/of lasten worden geëxternaliseerd of verschoven:* besluitvormers moeten het hele systeem en de hele levenscyclus van een product in ogenschouw nemen om ervoor te zorgen dat een schijnbaar circulaire innovatie de milieubelasting niet verschuift naar een andere levenscyclusfase. Het verkennen van de WRP ondersteunt besluitvormers om bewuster te zijn van de onderlinge afhankelijkheden en indirecte effecten van innovaties in een geglobaliseerde context.

In dit proefschrift heb ik de resultaten van mijn onderzoek gesynthetiseerd naar lessen voor strategievorming en governance. Deze lessen hebben betrekking op: het ontwikkelen van een geïntegreerde benadering van CE, het vergroten van meer aandacht voor verschillende soorten daadkracht en verschillende rollen, het creëren van specifieke voorwaarden voor een gunstige omgeving voor de ontwikkeling en verspreiding van CE-praktijken en het vaststellen van manieren om paradoxen en valkuilen in de transitie aan te pakken.

Op basis van mijn resultaten roep ik op tot veranderingen in bestaande systemen en in de onderliggende aannames waarop onze huidige toekomstvisie is gebouwd, en bied ik inzicht in besluitvorming binnen een circulaire context. Tot slot stel ik een agenda voor toekomstig onderzoek voor dat verder bouwt op mijn werk, en sluit ik af met een beschrijving van mijn eigen visie op een geactualiseerde circulaire economie – wat als het allemaal werkt?

APPENDIX:
PhD Portfolio

PhD Portfolio

Rachel Greer
Website: https://drift.eur.nl/people/rachel-greer/
LinkedIn: https://www.linkedin.com/in/rachellgreer/
Contact: greer@drift.eur.nl

Promotor:	Dr. Derk Loorbach
Daily supervisor:	Dr. Timo von Wirth
PhD Project:	Waste FEW ULL (Horizon 2020 & JPI Urban Europe)
PhD period:	06/2018 – 6/2022

PhD Courses

Graduate School courses

27/09/2018	Professionalism and Integrity in Research	1 ECTS
27/3 – 19/06/2020	How to Finish your PhD in Time	2.5 ECTS

Professional courses

06/08 – 17/08/2018	Dutch A1&A2.1 Intensive Course - German natives (EUR Language Center)	25 contact hours
04/06 – 18/06/2020	Your Next Step (EUR Training and Development Platform)	8 contact hours
16/09 – 9/12/2020	Dutch B2.2.1 for Highly Educated Persons (Leiden University)	24 contact hours
10/02 – 21/04/2021	Dutch B2.2.2 for Highly Educated Persons (Leiden University)	24 contact hours
08/03 – 10/05/2021	How to Deal with Perfectionism (EUR Training and Development Platform)	8 contact hours

International Conferences

03/04 – 05/04/2019	4th Network of Early Career Researchers in Sustainability Transitions (NEST) Conference *Oral presentation "Accelerating the transition to a circular economy: Diffusion pathways and future scenarios"*	Lisbon, Portugal
24/06 – 27/06/2019	10th International Sustainability Transitions (IST) Conference *Oral presentation "The transition towards a circular economy: Drivers and barriers for institutionalizing emergent niche services"*	Ottawa, Canada

07/07 – 11/07/2019	10th International Society for Industrial Ecology (ISIE) Conference *Oral presentation "The transition towards a circular economy: Drivers and barriers for institutionalizing emergent niche circular services"* *Session chair "NEWFW: Energy-Water-Food Nexus"*	Beijing, China
20/11 – 21/11/2019	JPI Urban Europe: Diffusion of Innovation from Urban Living Labs Workshop *Expert input in workshop sessions*	Maastricht, Netherlands
07/05 – 09/05/2020	5th Network of Early Career Researchers in Sustainability Transitions (NEST) Conference *Oral presentation "Transitioning from a linear to circular economy: Widening perspectives on the Waste-Resource Paradox"*	Zurich, Switzerland*
08/04 – 10/04/2021	6th Network of Early Career Researchers in Sustainability Transitions (NEST) Conference *Oral presentation "The Circular Decision-Making Tree: An operational model"* *Session chair "Circular Economy"* *Session chair "Business and Finance"*	Sofia, Bulgaria*
05/07 – 10/07/2021	5th International Conference on Public Policy (ICPP5) *Oral presentation "The Circular Decision-Making Tree: An operational model"*	Barcelona, Spain*
05/10 – 08/10/2021	12th International Sustainability Transitions (IST) Conference *Oral presentation "The Circular Decision-Making Tree: An operational model"*	Karlsruhe, Germany*
Conference and workshop organization		
26/09 – 28/09/2020	2nd Annual Waste FEW ULL international consortium meeting *Co-organizer of event*	Rotterdam, Netherlands
08/04 – 10/04/2021	6th Network of Early Career Researchers in Sustainability Transitions (NEST) Conference *Organizing committee* *Facilitator, session chair and presenter*	Sofia, Bulgaria*
14/04/2021	Break Free from Plastics Europe (Zero Waste Europe) In-Company Course *Reflector and moderator*	Rotterdam, Netherlands

A

Expert presentations		
10/10/2019	De Water-Energie-Voedsel Nexus in de Stad Conferentie *Oral presentation "The transition towards a circular economy: Drivers and barriers for institutionalizing emergent niche circular services"*	The Hague, Netherlands
29/10/2019	Verbinden van Duurzame Steden (VerDuS) Platform 31 *Interview "Circulariteit meenemen in beslissingen: hoe, wat en waarom?"* *https://www.verdus.nl/circulariteit-meenemen-in-beslissingen-hoe-wat-en-waarom/*	Rotterdam, Netherlands*
25/6/2020	Decision-Making in the Circular Economy Workshop *Oral presentation "Transition dynamics to a circular economy: Identifying decision-making parameters and tradeoffs"*	Rotterdam, Netherlands*
15/09/2020	Heuristics and Decision-making in the Circular Economy Workshop *Oral presentation "The Waste-Resource Paradox and Decision-making in the Circular Economy"*	Rotterdam, Netherlands*
25/02/2021	Waste FEW ULL Workshop: Decision-Making in the Circular Economy *Oral presentation "The Waste-Resource Paradox and the Circular Decision-Making Tree*	Bristol, United Kingdom*
07/04/2021	Webinar at University of California Santa Cruz, Faculty Earth and Planetary Sciences *Oral presentation "Urban Living Lab Rotterdam"*	Santa Cruz, USA*

* Moved online or hybrid setting, due to the COVID-19 pandemic.

PUBLICATIONS

Peer-reviewed publications in thesis

Greer, R., von Wirth, T., & Loorbach, D. (2020). The diffusion of circular services: Transforming the Dutch catering sector. *Journal of Cleaner Production, 267*, 121906. https://doi.org/10.1016/j.jclepro.2020.121906

Greer, R., von Wirth, T., & Loorbach, D. (2021). The Waste-Resource Paradox: Practical dilemmas and societal implications in the transition to a circular economy. *Journal of Cleaner Production, 303*, 126831. https://doi.org/10.1016/j.jclepro.2021.126831

Reports and working papers

Greer, R., von Wirth, T., & Loorbach, D. (2021). The Circular Decision-Making Tree: An operational heuristic. Conference paper, 5th International Conference on Public Policy (ICPP5), 5-9 July 2021, Barcelona, Spain.

Greer, R., van Raak, R., Schröer, L., & Scherpenisse, J. (2021). Evaluatie Versnellingshuis Nederland Circulair! Eindrapport. Rotterdam, Netherlands. https://www.rijksoverheid.nl/documenten/kamerstukken/2021/10/18/ aanbieding-uitvoeringsprogramma-circulaire-economie-2021-2023

Other peer-reviewed publications

Hebinck, A., Diercks, G., von Wirth, T., Beers, P., Barsties, L., Buchel, S., Greer, R., van Steenbergen, F., & Loorbach, D. (2022). An actionable understanding of societal transitions: the X-curve framework. *Sustainability Science*. DOI: 10.1007/s11625-021-01084-w

Accepted for publication with revisions in thesis

Greer, R., von Wirth, T., & Loorbach, D. (2022). The Circular Decision-Making Tree: An operational heuristic [Manuscript accepted for publication to *Circular Economy and Sustainability*]. Dutch Research Institute for Transitions (DRIFT), Erasmus University Rotterdam, Netherlands.

Papers and book chapters in preparation

Greer, R., von Wirth, T., & Loorbach, D. (2022). Rethinking sustainability in French viticulture: Challenging optimizations of the linear economy wine regime [Unpublished manuscript]. Dutch Research Institute for Transitions (DRIFT), Erasmus University Rotterdam, Netherlands.

Greer, R., & Wittmayer, J. (2022). The "Regime-Niche": Characteristics and dynamics of a catalyst in transitions. *The Routledge Handbook of Catalysts for a Sustainable Circular Economy* [Manuscript in preparation]. Dutch Research Institute for Transitions (DRIFT), Erasmus University Rotterdam, Netherlands.

Wei, T., Black, D., Greer, R., von Wirth, T., Schmutz, U., Fried, J., & Roderick, I. (2022). Income impacts of food waste in UK households: An input-output approach [Manuscript in preparation]. CICERO Center for International Climate Research, Zibo, China.

Peer reviews on publications for journal articles and book chapters

Simoens, M. C., & Leipold, S. (2021). Trading radical for incremental change: the politics of a circular economy transition in the German packaging sector. *Journal of Environmental Policy & Planning,* 1-15.

Wyckmans, A., Wang, Y., Korsnes, M., Aune, P., Yu, Y., Liu, C., Pasher, E., Harir, M., Sharir, L., Herzog, O., Cao, B., Kontinakis, N., & Colclough, A. (2021). Urban Living Labs as Instruments of Open Innovation: Examples of Sino–European Cooperation. In *Towards Socially Integrative Cities. Perspectives on Urban Sustainability in Europe and China.* Edited by Bernhard Müller, Jian Liu, Jianming Cai, Paulina, Schiappacasse, Hans-Martin Neumann and Baojun Yang. Basel: MDPI, Page Range. doi.org/10.3390/books978-3-03936-679-8