IIIEE Theses 2019:03

Building Institutional Capacity for Sustainability Transitions through Innovation Experiments

A Case Study of Sustainability Innovation Networks and Craft Beer SMEs

Brendan Pipkin

Supervisors

Dr. Barry Ness

Thesis for the fulfilment of the
Master of Science in Environmental Sciences, Policy & Management (MESPOM)
jointly operated by Lund University – University of Manchester -
University of the Aegean – Central European University

Lund, Sweden, June 2019

Erasmus Mundus Masters Course in
Environmental Sciences, Policy and Management

MESPOM

This thesis is submitted in fulfilment of the Master of Science degree awarded as a result of successful completion of the Erasmus Mundus Masters course in Environmental Sciences, Policy and Management (MESPOM) jointly operated by the University of the Aegean (Greece), Central European University (Hungary), Lund University (Sweden) and the University of Manchester (United Kingdom).

Published in 2016 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

ISSN 1401-9191

Acknowledgements

This thesis project has been an enlightening, challenging, and rewarding process. I have greatly enjoyed being able to dive into the mechanisms of sustainability movements through individual research, interviews with diverse stakeholders implementing fun projects, and conversations with my supervisor, teachers and classmates. It is to these folks I would like to extend my sincere gratitude for supporting me in this process.

Many thanks to my thesis supervisor, Barry Ness, who was always available to provide advice, guidance, and well-time levity throughout the semester that was crucial to navigating the thesis experience. To Yuliya Voytenko Palgan for preparing us to embrak on a massive research project and for letting me bother you with questions about experimentation theory and frameworks. And to teachers and course coordinators Naoko Tojo and Gyorgyi Puruczky for making the MESPOM experience so enjoyable and organized enough to allow us to focus on our studies.

I would also like to thank the many stakeholders who participated in interviews during this project. With very busy schedules, they were often eager to indulge my many questions and engage in broader discussions about sustainability, community and craft beer. Cheers.

Lastly, I'd like to acknowledge my classmates. This thesis was the cap on a fantastic shared journey with a great group of people, for which I am grateful to have had.

Abstract

The concept of experimentation is increasingly promoted to facilitate social learning for sustainability transitions. Experiments are collaborative initiatives designed to generate knowledge and test innovative practices to address a collective sustainability challenge. However, it is often unclear whether experiments generate any impact beyond the initial project scope. Recent literature has called for further research on how the dynamics and outcomes of sustainability experiments might lead to broader system transformation. This thesis applies the institutional capacity (IC) building framework to analyze the knowledge resources, relational resources, and mobilization capacity developed in two innovation networks experimenting with symbiotic resource exchanges in the craft beer sector – one utilizing unsold bread to offset malted barley in brewing in the UK, and one piloting the use of highly treated wastewater instead in the brewing process. Each case is characterized by the recent emergence of successive experiments conducted across growing communities of actors to from an innovation network. The study found that the collaborative experiments did boost overall levels of IC to further develop the respective practices. However, the capacity for further sustainability action is unevenly distributed among the innovation networks. Findings identified range of actors involved, their relative levels of commitment required to participate in the projects, and the resources they have available for further action as key factors influencing the different rates of growth and transformative potential of the networks. This supports prior research that found institutional support from established actors is important for an innovation to scale up. The findings also suggest that, if designed well, collaborative experimentation projects are a useful platform for small- and medium-sized enterprises (SMEs) to engage in open innovation and organizational learning processes for adoption of circular economy (CE) practices.

Keywords: Experimentation, Sustainability Transitions, Circular Economy, SMEs, Craft Beer

Executive Summary

Background & Problem Definition

The concept of real-world 'experimentation' is increasingly promoted as a means of sustainability transition governance that allows stakeholders to collaboratively explore, test, refine, and share innovations that can potentially scale up to address sustainability challenges (Bulkeley and Castan Broto 2013, Sengers et al., 2016). It is argued that the inclusive and challenge-based nature of sustainability experiments can facilitate practical learning outcomes, in terms of testing new socio-technical arrangements, and conceptual learning outcomes through development of a shared problem definition and a collective vision for action among stakeholders (Van Poeck et al., 2018, Frantzeskaki and Rok 2018). However, recent literature has highlighted knowledge gaps on whether sustainability experiments truly lead to broader change and what dynamics can support successful scaling of innovation experiments (Hilden et al., 2017, Bulkeley et al., 2016). Understanding these dynamics is critical to ensure strategic design and implementation of experiments that can achieve intended social learning goals and support sustainability transitions (Marvin et al., 2018, Matschoss and Heiskanen 2017).

Specifically, there is a need to comprehensively understand how the social learning goals and collaborative nature of sustainability experiments might increase the capacity of involved actors to build on the lessons learned and sustain the momentum developed from the experiment for continued innovation development. To address this knowledge gap, this thesis applies the institutional capacity (IC) building framework (Healey et al., 2003) to examine the knowledge resources, relational resources, and mobilization capacity developed in two case studies of sustainability experiments that have shown initial signs of scalability through successive experiments across national actor networks.

The two case studies examined here are each expanding networks of actors experimenting with innovative circular economy (CE) practices that recover value from food and water systems by converting former "waste" byproducts into a new input resource in the craft beer sector. One network is experimenting with diverting surplus bread from bakeries to offset a percentage of fresh malted barley in craft beer production. The other network involves water utilities showcasing the state of water reuse technology by hosting competitions and demonstrations of beer brewed with highly treated recycled water. Each network was catalyzed by a single, initial experiment with the practice that was replicated by other actors with increasing scales over time. The rapid growth and global media coverage of each experiment network suggested evidence of social learning, network building, and progressive levels of action that indicated potential for these sustainability experiments to support sustainability transitions.

Research Questions

This thesis aims to provide insight on how the dynamics of collaborative innovation experiments build institutional capacity for advancing innovative sustainability practices by developing knowledge resources, relational resources, and increased mobilization capacity among stakeholders. To achieve this aim, this thesis uses the following research question and sub-questions:

Did the emergence of collaborative experimentation networks increase the institutional capacity for sustainability transitions and economic circularity within participating craft beer SMEs and their communities?

- *Has social learning for sustainability occurred at the organizational level based on participation in collaborative experiments?*
- *Do actors feel increased capacity to implement the tested practice or other sustainable business model activities as a result of the knowledge and relational resources developed (if any)?*
- *Has sufficient institutional capacity been developed for these innovation networks to scale up the specific practice for socio-technical transformation?*

Methodology and Research Design

This research utilized an inductive case-based research approach by applying the IC-building analytical framework to two cases of sustainability experiment networks. The research was conducted in a multi-phase process consisting of academic and grey literature review for secondary data collection, semi-structured interviews with key stakeholders for primary data collection, and data coding and analysis in the data management program NVivo 12. Interview questionnaire templates and the data coding were designed according to the 12 specific indicators within the IC building framework pillars of knowledge resources, relational resources and mobilization capacity. Twenty-four interviews were conducted altogether, primarily in-person for organizations in the UK and by web call for organizations in the US.

Main Findings

This research found that each experimentation network did build overall institutional capacity for advancing the sustainability innovations being tested, but that the mobilization capacity developed was unevenly distributed among the networks. This means that some participating organizations in each network have improved their understanding of and ability to further implement the tested practice, while others experienced lesser learning or capacity building outcomes. However, despite uneven distribution of outcomes the experiments did collectively lead to increased knowledge resources, relational resources, and mobilization capacity across the networks that position the innovative practice to gain legitimacy and continue being scaled up within the food, water, and craft beer sectors. This demonstrates the importance of conducting successive experiments to build practical and learning outcomes across a network over time and of the benefit of studying sustainability experimentation in aggregate, as this will yield findings across the network that might not be manifested at each individual experiment level.

While the overall IC developed show the importance of further research at the network level, the IC building framework also shed light on the dynamics of individual experiments within each network. The uneven distribution of IC among actors was likely due to the design and implementation of the individual experiments within the overall networks, which are influenced by the relative 'power to act' among participating organizations, the extent of engagement in the overall network, and the levels of commitment and shared visioning required. In individual collaborative experiments, it was found the organizations who initiated the experiments often experienced the highest development of organizational knowledge resources, relational resources and mobilization capacity. This suggests that the inclusive nature of experiments does not necessarily result in shared outcomes, as the initiating organization often designs experiments to meet their own goals. This is not malicious but likely a result of actors operating from their own range of knowledge and perspectives. This suggests that experiments with deeper actor engagement throughout have more potential to develop shared problem definitions and visions among actors. For example, breweries who were consulted in the design of projects, and some who were given more responsibility for implementing their projects, experienced higher learning outcomes than those who were just invited to participate. Even when not participating in planning, the extent of engagement seems to directly affect learning outcomes. In the recovered bread network, breweries who

engaged in multiple collaboration projects experienced more higher learning outcomes than those that participated in a single collaboration project.

Conclusions and Recommendations

This research demonstrated that collaborative experimentation can lead to increased knowledge resources, relational resources, and mobilization capacity for stakeholders to explore and refine innovations that may scale up and accelerate sustainability transitions. Further, the application of the IC-building framework provides a useful method for researchers and practitioners to comprehensively understand the goals and outcomes of sustainability experimentation to have an impact. Further testing of the framework for experimentation is needed, but it appears to be applicable to the level of individual collaborative experiments as well as the overall experiment network level.

Based on the research findings, key recommendations for sustainability experiment practitioners and researchers include:

- Include relevant actors from various scales and perspectives, including grassroots and established regime actors, to facilitate broad knowledge bases and mobilization capacity
- Set clear practical outcomes and learning objectives to engage stakeholders in understanding a shared sustainability problem, collaboratively working toward a potential solution, and encouraging active and reflective learning throughout
- When possible, design experiments for multiple iterations to facilitate continued learning and actor engagement over time
- Leverage existing connections beyond immediate experiment networks to grow a larger stakeholder network and encourage more robust learning by testing the innovation in different settings
- For researchers, continue to study the individual dynamics of sustainability experiments for more insight on relative power dynamics among actors and the quality of learning outcomes
- Continue to test the IC Building framework at individual and collective network levels to better understand and inform experimentation design, implementation dynamics, and outcomes

Table of Contents

List of Figures

List of Tables

Abbreviations

CE - Circular Economy

IC - Institutional Capacity

Cleaner Production – CP

Eco-Innovation - EI

IS – Industrial symbiosis

SMEs – small- and medium-sized enterprises

1 Introduction

Sustainability transitions entail multidimensional transformations across all aspects of society, including new technologies, markets, public policies, social practices and institutional arrangements (Kivimaa et al., 2018, de Jesus and Mendonca, 2018). However, achieving transitions is inhibited by the limited institutional capacity of conventional governance to understand complex international issues that occur outside the realm of traditional government authority (Innes and Booher 2003, Frantzeskaki et al., 2012). Addressing this 'wicked problem' requires social learning to create a shared understanding of sustainability challenges among diverse stakeholders, real-world 'transition arenas' to deliberately explore and develop potential innovative solutions, and a strong network of multi-sector and multi-level actors to support such innovations for transformative impact (Filho et al., 2016, Tukker and Buter 2007).

Transition arenas are "institutional spaces in which multiple actors convene to allow exchange of ideas, dialogue on issues and solutions and interactions concerning target problems and their proposed solutions" (Frantzeskaki and Rok 2018). The goal is for participants to 'co-produce' new knowledge about sustainability transitions and build networks to collaboratively envision and enact transition (Frantzeskaki and Rok 2018, Frantzeskaki et al., 2012, Tukker and Butter 2007, Geels 2004).

The concept of collaborative 'experimentation' is increasingly promoted as such a transition arena for actors to explore, test, and share potential sustainability solutions (Loorbach and Rotmans 2006, Bulkeley and Castan Broto 2013). The idea is that "society is itself a laboratory and a variety of real-world actors commit to the messy experimental processes tied up with the introduction of alternative technologies and practices in order to purposively re-shape social and material realities" (Sengers et al., 2016). Proponents argue that sustainability experiments result in practical learning outcomes (e.g. better practices and understanding), relational learning outcomes (development of new societal arrangements and networks) and conceptual learning outcomes (e.g. aggregating and sharing knowledge) (Van Poeck et al., 2018). Importantly, collaborative experimentation may allow increased engagement among stakeholders who typically have limited capacity to engage in innovation experiments, such as municipal governments, small NGOs or civil society actors, and small- and medium-sized enterprises (SMEs) (Burch et al., 2018, Burch et al., 2016).

However, there are research gaps regarding the dynamics of collaborative experimentation and debate on the potential of experimentation to drive broader sustainability transitions (Hilden et al., 2017, Sengers et al., 2016, Bulkeley and Castan Broto 2013). As a nascent but rapidly growing field, there is limited comprehensive study of how governance actors can optimize sustainability experiments to develop knowledge of sustainability issues and build actor networks in a way that builds capacity to implement real action toward sustainability transitions (Antikainen et al., 2017, Raven et al., 2016).

One guiding concept of sustainability transitions is the circular economy (CE), an emerging but relatively ambiguous concept meant to shift sociotechnical systems of production and consumption to be more sustainable (Geissdoerfer et al., 2017, Lewandowski et al., 2016). CE entails transitioning from a linear "take-make-dispose" economic system to one that respects finite resource boundaries by minimizing resource demands, keeping resources and energy in use, and recovering new value from former 'waste' products (Prieto-Sandoval 2018, Ellen Macarthur Foundation 2013). Policy makers at local, national and global levels have begun prioritizing CE in economic and transition plans (Prendeville et al., 2018).

However, there are limited tangible examples of CE in practice, particularly for actors with limited innovation development resources such as local governments or small- and -medium-sized enterprises (SMEs) (Bocken et al., 2017). Collaborative experimentation therefore provides a useful tool for actors to explore, test, and learn about CE practices in protected niches through developing a shared understanding of sustainability challenges and potential solutions.

To empower governance systems to effectively utilize such experimentation for sustainability transitions, a comprehensive and flexible framework is needed to analyze the dynamics and outcomes of sustainability experiments (Marvin et al., 2018). Further, this should provide insight on how to harness experimentation networks for transformative impact.

1.1 Problem Definition

This thesis addresses knowledge gaps in the fields of experimentation and CE development for sustainability transitions by applying the institutional capacity (IC) building framework to two empirical case studies of innovation experiment networks. This provides insight on the dynamics of experimentation at a local level and at the system level by considering the emergent outcomes of multiple distributed experiments across an innovation network.

Recent investigations of experimentation literature highlight remaining questions "on why and how they emerge, who the agents are and what the experiments actually achieve" (Hilden et al., 2017). Sengers et al. (2016) remind us that "too often, sustainability-oriented experiments are isolated events that fade into oblivion without any effect on incumbent regimes." In considering how urban living labs (an emerging type of sustainability experimentation) contribute to governance of urban sustainability challenges, Bulkeley et al. (2016) claim the challenge is to study "if and how such an experimental approach can create an impact beyond their immediate domain and induce transitions across urban socio-technical and socio-ecological systems."

One specific area of interest is the co-production of knowledge and learning processes associated with experimentation. Though it is often assumed that valuable learning takes place in sustainability transition experiments, researchers have identified the need to examine the types and quality of social learning that occur (Van Poeck et al., 2018, Colvin et al., 2014). This is important to determine outcomes at various scales - whether the individual actors involved experienced practical and conceptual learning that will actually help them act more sustainably, and whether the aggregate knowledge developed through multi-stakeholder experimentation will lead to a more sustainable socio-technical system (Matschoss and Heiskanen 2017).

There are similar issues in the field of circular economy development. Though there is a high-level conceptual vision, there is debate about how to foster learning and innovation to implement circularity in practice (Kalmykova et al., 2018, Blomsma 2018). Business model experimentation for sustainability has been promoted as an "intentional and systematic approach to identify, test and learn about value creation strategies that could be adopted by a business in response to current unsustainable trajectories" (Bocken et al., 2018). However, despite considerable efforts to promote forms of eco-innovation activities and sustainable business model innovation across socio-technical systems there has been lackluster implementation in practice, particularly among small and medium sized enterprises (SMEs) (Pigosso et al., 2018, Ormazabal et al., 2018).

There may be direct synergies between sustainability experimentation and organizational experimentation for eco-innovation and CE development (Baldassare et al., 2017, Powells et al., 2016, Bidmon et al., 2018). Community groups, municipal governments, and SMEs have emerged as key actors in localized sustainability experiments and transitions (Burch et al., 2016, Powells et al., 2016). Burch et al. (2018) argue that "SMEs have untapped potential for innovation as they seek ways to reduce costs, win new customers, receive good publicity and have higher staff retention." Some 'frontrunner' SMEs even view themselves explicitly as agents of change that are motivated by ideals other than pure profit-making activities, often including an openness to experimenting with radical innovations (Burch et al., 2018, Boiral et al., 2014). This makes these groups ideal partners to collaboratively experiment with circular sustainability innovations they would not otherwise have capacity to explore.

The two case studies being analyzed are emerging experimentation networks testing new methods of value creation across the beer, food, and water sectors. These craft breweries and community networks are utilizing creative sustainability innovations to integrate resource efficiency and social value into their organizational models in the form of circular economy experiments with explicit social learning goals. These innovative practices seek to utilize surplus bread and recovered water, respectively, as inputs to the brewing process in ways that may inspire new social conceptions of resource use norms in society.

1.2 Objective and Research Questions

This research project examines how collaborative innovation experiments build institutional capacity for advancing circular economy and sustainability practices among craft beer SMEs and their stakeholders by developing knowledge resources, relational resources, and mobilization capacity.

Specifically, the research analyzes the emergence of two identified innovation networks that have developed around innovative industrial symbiosis (IS) practices in craft brewing, and which have utilized multi-stakeholder experimentation and demonstration projects to facilitate collaboration, knowledge sharing, and action around a shared vision. This includes examination of experimentation dynamics at the individual organizational level and the regional collaboration level to analyze the IC built at the overall innovation network level.

The two experiment case studies chosen are both collaborative circular economy experiments that were initiated by actors external to the beer industry and have quickly grown to form a network of (more or less) linked regional experiment stakeholder groups. As such, these case studies provide robust insight on the micro-level dynamics of sustainability experiments, the potential institutional capacity emerging from societal learning and network building through experimentation, and the potential for increased institutional capacity to drive socio-technical transitions.

Research Questions

This thesis achieves the stated objectives by answering the following research question:

Did the emergence of collaborative experimentation networks increase the institutional capacity for sustainability transitions and economic circularity within participating craft beer SMEs and their communities?

To provide insight on this overarching question, the following sub-research questions were explored:

1. *Has social learning for sustainability occurred at the organizational level based on participation in collaborative experiments?*
2. *Do actors feel increased capacity to implement the tested practice or other sustainable business model activities as a result of the knowledge and relational resources developed (if any)?*
3. *Has sufficient institutional capacity been developed for these innovation networks to scale up the specific practice for socio-technical transformation?*

1.3 Scope and Limitations

The scope of this research project contains two sustainability innovation networks experimenting with symbiotic exchange of surplus bread in the United Kingdom and recycled water in the United States, respectively. This scope was deemed appropriate to provide robust insights on the dynamics of experimentation networks at the individual, regional, and overall network levels of institutional capacity building, within a clear spatial and temporal boundary. Further, the selection of experiments utilizing SME partners was chosen to include practical results for the development of eco-innovation and circular economy practices in SMEs.

Based on the research goals, two innovation networks were chosen that consisted of multi-stakeholder experimentation projects with clear signs of replication and growth through a direct network of actors. In this case industrial symbiosis experiments represented the need to develop cross-sector partnerships with clear goals of developing knowledge and relational networks to drive sustainability action.

Further, the two cases chosen have received significant global media attention for their unique and innovative nature. Despite consisting of mostly small, regional experiments, the projects have shown ability to engage audiences well beyond the project locations through effective storytelling and use of a popular product – craft beer - to demonstrate circular economy practices and raise awareness about sustainability issues.

The research aimed to provide a comprehensive analysis of the overall networks with deeper study of specific regional collaborations as relevant. The sampling of interviewees was chosen from each case based on the organizations identified to be the main actors in each network. Out of the more peripheral actors (who participated loosely or briefly but did not remain engaged), interviewees sampled were based on the number of willing respondents. There were enough interviewees to provide good insight on the different regional collaborations and various actor perspectives across each network. One limitation may be that the organizations willing to participate in interviews were inherently more engaged than those who did not respond to interview requests. However, interview responses seemed to yield diverse results and enough consistency to give a coherent picture of the range of participating actors.

The main research goal was to analyze the overall levels of institutional capacity resulting from the collective development of knowledge resources, relational resources, and mobilization capacity from regional projects spreading to a distributed network level. The paper does not explicitly aim to answer questions about the depth or quality of social learning learning at the organizational or individual actor level, or the ability of these specific practices to scale up into their respective sociotechnical regimes. However, these topics are considered through research as supplementary insights to the system level findings.

The project also does not concern itself with the various definitions of what defines a 'craft' brewery in terms of ownership. This discourse will be addressed briefly in the literature

review, but the scope of research simply focuses on organizations involved in the network. These are mostly characterized as craft beer SMEs, but some in the UK this includes some small breweries with larger ownership groups.

1.4 Ethical Considerations

This research design follows principles for ethical social science research as provided by the European Commission (2018). All interviews were voluntary and recorded with permission from interviewees. The purpose of the research interviews was communicated when actors were contacted for interviews, and again at the beginning of each interview. The identities of specific interviewees will remain anonymous except where permission has been explicitly given.

The names of craft beer SMEs organizations involved in the network are also kept anonymous to prevent this research from becoming promotional. However, the names of public agencies involved in the projects are used (though the specific interviewee names are not).

1.5 Audience

This thesis provides useful contributions to the academic community studying sustainability experimentation governance and the real-world actors interested in collaborative experimentation as a means of developing knowledge and relational resources to support circular economy or sustainability transitions. As such, interested audiences may include researchers, policy makers, not-for-profit organizations, and small and medium sized enterprises hoping to engage in open innovation processes.

1.6 Disposition

This thesis is presented in the following format. *Section 1* presents the problem background, aims and objectives of research, the scope and research limitations, and lays the foundation for the research paper.

Section 2 contains a summary of the literature review on sustainability transitions and circular economy development. It then presents the analytical framework used for this research and provides background on the case studies selected to be examined.

Section 3 provides the research design and methodology of the project. This comes after the literature review because the literature review and its presentation of the IC framework informed the research aims and methodology.

Section 4 presents the findings from the two case studies, organized according to the analytical framework pillars of relational resources, knowledge resources and mobilization capacity.

Section 5 provides analysis and discussion of the findings in relation to the overall levels of IC developed, the implications for experimentation and sustainability transition literature, the transformative potential of the innovation networks, and the applicability of the IC framework in studying experimentation network dynamics.

Lastly, *Section 6* provides conclusions of the research and analysis and recommendations for decision makers and the research community.

2 Literature Review

2.1 Sustainability Transitions

Sustainability transitions require long-term, multidimensional transformation of all aspects of society to achieve sustainable development goals, which aim to meet "the needs of the present without compromising the ability of future generations to meet their own needs" (Keeble 1988, Kivimaa et al., 2018). Transforming systems of production and consumption to be sustainable requires both technological developments and fundamental changes in governance systems, economic paradigms, and social norms (de Jesus and Mendonça 2018, Patterson et al., 2017).

Existing governance systems have proven inadequate to sufficiently address the complexity and uncertainty of a world facing climate change, finite resource boundaries, and numerous other environmental, social and economic issues (de Coninck et al., 2018, Birkmann et al., 2010). Frantzeskaki et al., (2012) summarize the challenge as a contradiction between "the open-ended and necessarily uncertain character of progress towards sustainability and the societal ambition to control, orient and manage this process…" and "an inherent tension between the aspiration for long-term, radical, but quite-uncertain change, on the one hand, and practical and short-term needs for specificity, compromise and small steps, on the other." Essentially, society must begin acting immediately to solve a a problem it does not fully understand by identifying and urgently enacting solutions that are not yet known.

This lack of capacity in conventional governance to address dynamic uncertainty (Innes and Booher 2003) has driven a shift toward increasingly distributed, collaborative, and experimental governance systems (Tukker and Butter 2007, Filho et al., 2016). Köhler et al., (2019) define modern sustainability transition governance as "the totality of interactions, in which public as well as private actors participate, aimed at solving societal problems or creating societal opportunities; attending to the institutions as contexts for the governing interactions, and establishing a normative foundation for all those activities." This necessitates a sense of collective agency in driving sustainability transitions as multi-actor processes involving complex relationships between institutions and socio-technical transformation (Köhler et al., 2019, Kivimaa et al., 2018).

The following literature review will provide relevant background on the concepts of socio-technical system transitions for sustainability and the governance of transitions through social learning, network building, experimentation, and development of a circular economy. Lastly, the conceptual framework of institutional capacity building is introduced and proposed to analyze the outcomes of sustainability governance experiments in terms of knowledge resources, relational resources, and mobilization capacity developed.

2.1.1 Socio-technical Transitions

Sustainability transitions are dependent on transforming the various 'socio-technical systems' that meet societal needs, such as energy, water, food, and mobility systems (Markard et al., 2012, Geels 2004, Kivimaa et al., 2018). A socio-technical system is comprised of "an interdependent and co-evolving mix of technologies, supply chains, infrastructures, markets, regulations, user practices and cultural meanings" (Geels 2018). These established actors and arrangements are considered the socio-technical 'regime,' which maintain stability and inherently resist radical change, thereby limiting the exploration and uptake of innovative technologies, practices, or perspectives that may threaten the system's norms (Geels 2004).

Socio-technical system transitions are conceptualized in multi-level perspective (MLP) and strategic niche management (SNM) literature that "views transitions as non-linear processes that results from the interplay of developments at three analytical levels: niches (the locus for radical innovations), socio-technical regimes (the locus of established practices and associated rules that stabilize existing systems), and an exogenous socio-technical landscape" (Geels 2011, Kivimaa and Kern 2016). Niches are protected spaces where radical innovations can develop within broader socio-technical regimes made up of established technologies, practices and institutions that stabilize the existing system (Geels 2011, Kivimaa et al., 2018). As an innovation at the niche level gains a foothold within the socio-technical regime, it can be supported and scaled up to become a part of the incumbent regime or to transform the socio-technical system entirely (Geels and Schot 2007). The interaction between niches and established regimes take place within the conceptual "socio-technical landscape," which represents external context that influences the sociotechnical system such as economic trends, public perceptions, political events, regulatory changes or public interest in an environmental issue (Geels and Kemp 2007).

2.1.2 Governing Transitions

While these concepts provide useful descriptive theory of system transitions, they bring limited attention to actor agency in protecting and developing niche innovations to influence a regime (Frantzeskaki et al., 2012). Sustainability transitions are an inherently political and contested process due to different socially constructed narratives of problem definition, potential solutions, the dynamics of transition, and who ultimately 'wins or loses' (Patterson et al., 2017, Köhler et al., 2019). Therefore, the processes and dynamics of transition are necessarily influenced by implicit and explicit actor perspective and interests.

To address agency in transition, the fields of transition management (TM) and technological innovation systems (TIS) theorize sociotechnical system governance as a reflexive process that incorporates evolving information for adaptive societal systems through "a combination of problem structuring and envisioning in multi-stakeholder arenas, developing new coalitions, implementing agendas in experiments, and evaluating and monitoring the process" (Markard et al., 2012, Loorbach and Rotmans 2006). Such multi-stakeholder arenas are conceptualized as niches in which to engage actors in deliberately fostering socio-technical innovations geared toward sustainability (Loorbach and Rotmans 2006, Tukker and Butter 2007, Kivimaa and Kern 2016, Smith and Raven 2012). Importantly, this recognizes the need for actors to proactively integrate explicit sustainability goals into new and existing institutional structures while co-producing knowledge of potential solutions and building diverse actor networks to support transition (Filho et al., 2016, Frantzeskaki et al., 2012).

The field of sustainability transitions is increasingly informed by interdisciplinary literature to navigate the tricky socio-political aspects of managing innovation and system transformation (Köhler et al., 2019). Prominent connections are being drawn with the concepts of social learning (Loorbach and Rotmans 2006, van Poeck 2018, Beers et al., 2016), actor networks (Farla et al., 2012), experimentation (Bulkeley and Castan Broto 2013, Marvin et al., 2018). adaptivity (Pahl-Wostl et al., 2009), agency and relative power to act (Burch et al., 2018), business and industry (Ellen Macarthur Foundation 2013, Geissdoerfer et al., 2017) and the geography of transitions (Murphy 2015, Hansen and Coenen 2015).

2.1.3 The Role of Social Learning

Sustainability transitions require many actors in different sectors to collaborate for collective social learning and action (Pahl-Wostl et al., 2013, Wittmayer et al., 2017). The social learning

concept stems from system innovation studies which view human systems as complex structures comprising diverse actors and their varied experiences, world views, and interpretations of a perceived problem and potential solution within the context of the system (van Mierlo et al., 2010, Patterson et al., 2017).

Social learning is considered important for sustainability transitions for its potential to create enhanced capacity to address complex transition issues, to build societal intelligence through collective change in consciousness and perceived solutions, to inform better governance systems with capacity to adapt to complexity and uncertainty, and to foster the creativity essential for questioning traditional assumptions and envisioning new futures (van Poeck et al., 2018, Filho et al., 2016, Hilden et al., 2017).

Social learning processes should allow networks of stakeholders to contribute unique perspectives to processes of collaborative action, reflective learning, and knowledge sharing for the institutionalization of sustainability concepts and practices (Sol et al., 2013, Pahl-Wostl 2009). This "learning by doing" is considered an innovative method of aggregating new knowledge and practices through stakeholder participation (Filho et al., 2016, van Poeck et al., 2018, Hilden et al., 2017).

Social learning can be facilitated through multi-stakeholder engagement spaces, which provide lessons "relevant for designing, organizing and institutionalizing interactions and co-production processes amongst all new actors that play, or can potentially play a role in accelerating sustainability transitions" (Frantzeskaki and Rok 2018). Conceptualizations of multi-stakeholder engagement spaces includes sustainability experiments, local transition initiatives, pilot or demonstration projects, and urban living labs (Sengers et al., 2016, Huguenin and Jeannerat 2017).

However, there remains limited understanding or proper utilization of social learning processes for sustainability transitions (Beers et al., 2016). The specific types of social learning that are desired from sustainability experiments should include practical learning outcomes (e.g. better practices and understanding), relational learning outcomes (development of new social arrangements and networks) and conceptual learning outcomes (e.g. aggregating and sharing knowledge) (van Poeck et al., 2018). It is assumed that if social learning creates a sufficient knowledge base and shared perspective among a network of actors, those actors will continue to test and adapt potential sustainability innovations for system transitions (Spekkink 2015).

2.1.4 The Role of Actor Networks

Early criticisms of sustainability transition literature are that it provides an oversimplified view of transition dynamics with limited attention to actors and agency (Farla et al., 2012, Markard et al., 2012). Sustainability transitions are nuanced and integrative processes that potentially affect many different stakeholders in different ways, providing actors with varying, and often conflicting, perspectives of the perceived problem, potential solutions and methods of transition (Khan 2013, Patterson et al., 2017).

It is important for actors to understand and negotiate their own interests and desires, as well as those of other actors, to develop shared problem definitions and negotiate a somewhat shared vision of action (Frantzeskaki et al., 2012, Innes and Booher 1999). Stemming from social and institutional streams of literature, stakeholder engagement in transition processes is increasingly acknowledged as a key aspect of governing socio-technical transitions toward sustainability (Fuenfschilling and Truffer 2016, Carvalho et al., 2017, Wittmayer et al., 2017).

A broad range of stakeholders must be included in deliberative decision-making processes for governance of sustainability transitions to be considered legitimate and equitable and to ultimately have any effect (Frantzeskaki et al., 2012).

Further study is needed on how actor networks can drive system change toward sustainability (Khan 2013). Burch et al., (2018) argue that "the ways that actor groups interact, build strategic alliances and exercise power may shed light on how to manage innovation, replicate successful experiments at other scales and contexts and address problematic or dysfunctional relationships." There is still a need to examine how specific actor roles and activities are enacted (or not) in processes of sustainability governance, social learning, experimentation transition (Wittmayer et al., 2017, Burch et al., 2018, Farla et al., 2012).

Sustainability governance networks can include public policymakers and organizations, associations, research institutes, civil society groups, and individuals (Farla et al., 2012, Wittmayer et al., 2017). Actors are characterized by the ability to pursue strategies, with resources and some freedom of decision-making (though constrained by the institutional structures in which they operate) to implement those strategies (Farla et al., 2012). Actor roles have been conceptualized based on the way their actions foster or inhibit system transformation (Wittmayer et al., 2017). For example, actors can lead innovation processes, be facilitators and connectors, act to transform institutional systems, or, conversely, act to maintain system stability (de Haan and Rotmans 2018).

Three prominent conceptualizations of actor roles that actively support transitions are 'frontrunners' (Markard et al., 2012), 'champions' (Taylor et al., 2012), and 'intermediaries' (Howells 2006, Gliedt 2018). Champions are innovation leaders within an organization or sector who are typically highly motivated and often show characteristics of confidence, enthusiasm, and persistence that creates personal power to exercise influence (Taylor et al., 2011, Taylor et al., 2012). Frontrunners are actors "with specific competencies and innovative ideas or practices with regard to a persistent problem," who can share their learning experiences and contribute to collective visioning within a transition arena (Wittmayer et al., 2017, Sengers et al., 2016). Lastly, intermediary actors are considered key facilitators of niche innovations with potential to accelerate transitions (Gliedt et al., 2018, Klerkx and Aarts 2013, Kivimaa et al., 2018). Based on a systematic literature review, Kivimaa et al., (2018) define transition intermediaries as "actors and platforms that positively influence sustainability transition processes by linking actors and activities… or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical system change, to create new collaborations within and across niche technologies, ideas and markets, and to disrupt dominant unsustainable socio-technical configurations." Intermediation takes many forms and is a crucial element to socio-technical transitions, especially in its potential to facilitate collective action across or between sociotechnical levels (Wittmayer et al., 2017).

Individual actors can fulfill multiple roles in aiding transition, or different roles at different times (de haan and Rotmans 2018, Wittmayer et al., 2017). Different actor roles contribute to fostering change in different ways (which may be cohesive or conflicting) and can be present or absent at different phases of transition (Klerkx and Aarts 2013, Farla et al., 2012). In order for actor networks to create change, they must be able to engage in and manage social learning processes to create a shared knowledge base, including development of somewhat shared problem definitions and potential solutions, and the network must include actors with resources to advance implementation strategies (Abreu and Ceglia 2018).

2.1.5 Governing through Experimentation

The concept of 'experimentation' is increasingly promoted as a method of facilitating social learning and building stakeholder networks to address collective sustainability challenges (Bulkeley and Castan Broto 2013, Sengers et al., 2016, Bosch-Ohlenshlager 2010, Ehnert et al., 2018). Experimentation for sustainability innovation is derived from a social constructivist position, in which "society is itself a laboratory and a variety of real-world actors commit to the messy experimental processes tied up with the introduction of alternative technologies and practices in order to purposively re-shape social and material realities" (Sengers et al., 2016). This stems partially from sociotechnical transition literature in which 'bounded socio-technical experiments' are utilized to test a new technology or practice with protection from market forces in order to develop and potentially influence the established regime (Geels and Kemp 2007, Sengers et al., 2018, Fuenfschilling and Truffer 2014).

Similarly, sustainability attention is considered a means of collaboratively visioning, testing and sharing potential socio-technical innovations (new technologies, practices or institutional arrangements) in somewhat protected real-world niches (Loorbach and Rotmans 2006, Voytenko et al., 2016, Sengers et al., 2018). In a systemic review of emerging sustainability experimentation literature, Sengers et al., (2016) proposed a comprehensive definition of an experiment as "an inclusive, practice-based and challenge-led initiative designed to promote system innovation through social learning under conditions of uncertainty and ambiguity."

Experimentation is being utilized across the governance spectrum, most prominently for technological innovations with user communities (Geels and Kemp 2007, Mossberg et al., 2018, Voytenko et al., 2016); urban living laboratories experimenting with new sociotechnical arrangements (e.g. for mobility, smart cities, energy systems, etc. (Bulkeley and Castan Broto 2013); and for sustainable business models and economic circularity (Baldassarre et al., 2017, Bocken et al., 2016, Bocken et al., 2017).

Inherent in the interest of experimentation is the idea that such experimentation leads to learning outcomes which can inform sustainability transitions (van Poeck et al., 2018). This is important for creating tangible, visible and positive scenarios of sustainable development to shift the climate discourse that is often characterized by 'doom and gloom' (Edwards and Bulkeley 2018). Sustainability experiments provide a chance to demonstrate that quality of life can be improved, rather than inhibited, through an informed and equitable transition governance process (Edwards and Bulkeley 2018, Bulkeley and Castan Broto 2013).

Further research is needed to understand the dynamics and impacts of sustainability experimentation in terms of actual learning outcomes (van Poeck et al., 2018, Hilden et al., 2017), the roles of power and agency of experimentation actors (Sengers et al., 2016, Weiland et al., 2017, Burch et al., 2018, Frantzeskaki and Rok 2018), the importance of geography and local embeddedness of experiment initiatives, the role of 'sense of place' and collective responsibility among actors (van den Heiligenberg et al., 2017, Burch et al., 2018, Frantzeskaki et al., 2018), and the ways in which niche experimentation might scale up to drive system transformation (Sengers et al., 2016, Hilden et al., 2017, Bulkeley et al., 2016). There have also been explicit calls to move beyond studying individual experiment initiatives to analyze broader experiment datasets to identify factors of success or failure and "deploy network analysis to grasp how experiments are connected across locations and the kind of flows that go through them" (Sengers et al., 2016, Weiland et al., 2017). Further, there is a need for analytical frameworks to better understand the dynamics and outcomes of

experiments for experimental governance to be utilized most effectively (Marvin et al., 2018, Astbury and Bulkeley 2018, Weiland et al., 2017).

2.2 Transitioning to a Circular Economy

2.2.1 Theoretical Background of Circular Economy

A major goal of sustainability transitions is to develop sociotechnical systems of production and consumption that minimize carbon emissions, respect finite planetary boundaries in resource use, and balance stable economic activity with environmental and social health (Bocken et al., 2014, Geissdoerfer 2017). Policy makers and academia have been promoting the concept of a circular economy (CE) which entails shifting from a linear "take-make-dispose" economic system to one that most efficiently utilizes and maintains value by reducing new resource inputs, maintaining values by keeping resources in use longer, and actively regenerating natural systems (Ellen Macarthur Foundation 2013, Ritzén and Sandstrom 2017, Blomsma 2018).

CE is a contested concept within sustainability transitions - proponents believe it can balance human prosperity with environmental health for sustainable development, while critics suggest it perpetuates neoliberal economic growth values instead of truly addressing root causes of unsustainability (Kirchherr et al., 2017, Korhonen et al., 2018, Hobson and Lynch 2016). In this sense "CE is not described necessarily as a disruptive concept, but rather as a workable socio-technical approach for attaining economic and ecological sustainability" (de Jesus and Mendonça 2018).

Working toward a CE involves stepwise processes of sustainability integration in business models and institutions (de Jesus et al., 2018, Kalmykova et al., 2018, Marra et al., 2018, Bocken et al., 2019, Lewandowski 2016). The CE concept has emerged from an evolving body of 'green economy' literature that has contributed both practical and theoretical foundations to CE development (Kirchherr et al., 2017, Blomsma 2018). These connections are important because as research has focused on macro-level transitions to a circular economy, the mechanisms that actually lead to implementation of circular practices at the micro-level are often overlooked (Sousa-Zomer et al., 2018).

2.2.2 Development of Circular Economy

Developing a CE at the macro level is contingent on proliferation of sustainable practices and business models at individual firm levels (Bocken et al., 2014, Bolton and Hannon 2016, Levänen et al., 2018, Souza-Zomer et al., 2018). CE is conceptualized at the individual business level as strategies and business models that minimize new resource use by designing out waste, using clean production practices, and utilizing end-of-life materials as a new resource (e.g. repurposing, remanufacturing or recycling instead of disposal) (Bocken et al., 2014, Geissdoerfer et al., 2017, Kalmykova et al., 2018). However, there is often a disconnect between institutional support for change, such as government regulatory or incentive programs or shifting normative values, and the actual awareness or adoption of such practices at the business level (Levänen et al., 2018, Bolton and Hannon 2016, Bouncken and Fredrich 2016).

The more established principles of cleaner production (CP) and eco-innovation (EI) are considered antecedents to CE, with practices that pave the way for circular business strategies including input substitution (to reduce and substitute natural resource inputs, e.g. by increasing share of renewable or recovered resources); resource efficiency improvements

and internal recycling; technological optimization; and collaborative systems management perspectives (Souza-Zomer et al.,. 2018, de Jesus and Mendonça 2018, Prieto-Sandoval et al., 2018, Dieleman 2007). These can also support CE by developing managerial knowledge of sustainable business activities, raising awareness of business model relationships with societal contexts, and informing organizational shifts toward sustainability-oriented systems thinking (Lewandowski 2016, Hojnik and Ruzzier 2016, de Jesus and Mendonça 2018, Souza-Zomer et al., 2018).

The industrial ecology concept of industrial symbiosis (IS) provides another important foundation for CE due to its collaborative nature and system complexity (Saavedra et al., 2018, Abreu and Ceglia 2018). Whereas CP and EI occur within an organization, IS and CE both require cooperation between multiple actors for resource optimization. IS is the synergetic exchange between industries of materials, energy, water and by-products to collectively optimize the value of resources within a regional system (Mirata and Emtairah 2005, Chertow 2007, Boons et al., 2011). IS literature can inform CE through its ability to identify new types of value from formerly 'wasted' material streams, its consideration of knowledge generation and social learning for IS systems of actor networks to identify and facilitate synergies (Boons et al., 2011, Saavedra et al., 2018).

However, despite considerable efforts to promote these more sustainable practices across socio-technical systems, there has been lackluster implementation in practice - particularly among small- and medium-sized enterprises (SMEs) (Pigosso et al., 2018). SMEs often lack knowledge, time, and resources to learn about or implement sustainability programs (Bossle et al., 2016). Various internal factors including management support, a shared vision, and the desire or capacity to learn can enable knowledge development for sustainability innovation in SMEs (Johnson 2017). External factors can further support sustainability in SMEs, such as increasingly environmentally focused consumer preferences, sustainability policies, and the development of "communities of practice" in which SMEs can develop capacity, skills and knowledge (Rizos et al., 2016, Levänen et al., 2018, Marra et al., 2018). It is therefore important to examine the dynamics by which organizational eco-innovation can be developed within a socio-technical system and protected to drive transitions towards a more circular economy (de Jesus and Mendonça 2018. Marra et al., 2018).

Additionally, while there are substantial real-world applications of CP practices, IS exchanges, and related types of environmental management, there are less clear examples of the CE concept of creating environment and society value (in addition to financial) (Abreu and Ceglia 2018, Kirchherr et al., 2017, Prieto-Sandoval et al., 2018). The concept suggests that a business can create value by contributing to societal or environmental goals through their business model (Bocken et al., 2018). Tangible demonstrations of such alternate value creation are needed to demonstrate and drive such a paradigm shift (Bocken et al., 2014, Prieto-Sandoval et al., 2018, Marra et al., 2018). As with broader sustainability transitions, business model experimentation for sustainability has been identified as an "intentional and systematic approach to identify, test and learn about value creation strategies that could be adopted by a business in response to current unsustainable trajectories" (Bocken et al., 2018).

2.2.3 Small- and Medium-Sized Enterprises (SMEs)

While some studies and stories have emerged focused on new start-up models or large corporate businesses embracing sustainability, it is also important to enable sustainable business practices among the small- to medium-sized enterprises (SMEs) which comprise a majority of all businesses (Quintas et al., 2018). SMEs face barriers in trying to implement circular business strategies including limited power over supply chains or market demands,

financial constraints, and limited awareness of circular economy benefits. Factors that encourage sustainability practices include company culture, "a local or regional network with other SMEs and supporting multipliers to enhance information sharing and awareness raising," and perceived competitive advantage due to green marketing (Rizos et al., 2016).

As SMEs have more limited resources to engage in research and development themselves, they can utilize open innovation (OI) processes that facilitate innovation testing and knowledge flow among a network of partners (Yoon et al., 2016, Cheng et al., 2016, Behnam et al., 2018). A review of knowledge acquisition and development in sustainability-oriented SMEs found that internal capacities (e.g. top management support, shared vision, and room for learning) in SME can foster organizational learning, but that learning through OI requires high quality communication and collaboration among the innovation network stakeholders (Johnson 2017).

The threads of literature on integrating circular economy principles, identifying and creating new types of values, and fostering shared innovation knowledge and practices in SMEs are fairly new and not widely tested. Examination of specific case studies is needed to shed light on the ability of collaborative open innovation experiments as a process to explore new value creation models and boost sustainability awareness and knowledge sharing (social learning) among SMEs.

2.3 Analytical Framework: Institutional Capacity Building

This research proposes and applies the institutional capacity building framework as a method to study collaborative sustainability experiments at various levels. This framework is used for its ability to comprehensively analysing learning, network building, and overall capacity for action among a group of stakeholders. As such, it is suitable to address many of the research gaps identified in the previous section regarding sustainability experimentation dynamics and outcomes generally, and the use of collaborative experimentation as a means of open innovation for circular economy practices specifically. This section will introduce the theoretical foundations of the theory and explain its application in this study.

2.3.1 Theoretical Foundations

The concept of institutional capacity (IC) and institutional capacity building stems from urban planning and governance literature (Healey et al., 1999, Healey et al., 2003) and has recently been applied to examine the development of industrial symbiosis networks (Boons et al., 2011, Boons and Spekkink 2012, Spekkink 2013).

IC is considered the ability of a community of actors to mobilize collective action toward a common goal (Healey et al., 1999). Institutional capacity building describes the activities that help develop knowledge resources, relational resources, and mobilization capacity for such collective action. Spekkink (2013) explains that:

> "the concept is based on the understanding that to address issues of common concern in a collaborative fashion there should be a network of actors that trust each other and have some level of mutual understanding (relational resources), that have shared definitions of problems and solutions (knowledge resources)… and that among them are actors with sufficient power and resources to mobilize others for action (mobilization capacity)."

Therefore IC is not viewed as a stable stock of assets, but an emergent outcome of institutional capacity building processes (Healey et al., 2003, Boons 2011, Wang et al., 2017). As IC is the capacity of a community to act toward a collective goal (often a solution to a problem), a major characteristic of IC building is developing a shared problem definition and perceived opportunity for action (Spekkink 2015, Wang et al., 2017).

This is informed by interactions among members who each have various types of knowledge, different experiences and perspectives, various levels of openness to learning about new ideas and practices (Boons 2011, Spekkink 2013). The number and diversity of actors involved in the community, and their capacity for collaboration and ability to act, significantly influence the knowledge base and levels of knowledge sharing within the community (Spekkink 2015). While strong knowledge and stakeholder bases are important, mobilization capacity (the ability to utilize knowledge and relational resources toward a collective goal) is the most significant element of the IS framework (Wang et al., 2017).

As seen in Table 1, the variables of knowledge resources, relational resources and mobilization capacity are each supported by a set of interrelated indicators introduced by Healey et al., (2003):

> *Knowledge Resources* are comprised of the "range of knowledge resources" to which participants have access; "frames of reference" which shape actor perspectives; "extent of integration" of knowledge and frames of reference among stakeholders; and "openness and learning" of actors.
>
> *Relational resources* are measured by the "range of stakeholders" involved in a network; the "morphology of social networks" in terms of density and structure; the extent of "integration of networks;" and respective "the power to act" held by different actors.
>
> *Mobilization capacity* is indicated by the "opportunity structures" perceived by actors; "institutional arenas" in which stakeholders are engaging; the "repertoire of mobilisation techniques" used to develop and sustain project momentum, and the presence or absence of "critical change agents" at different stages.

The IC framework was developed and applied by Healey et al., (1999, 2003) to examine how institutional capacity grew over time through an urban regeneration project in Newcastle. This was an effective way to analyze distributed governance capacities among different societal actors. Though it was not yet considered or studied as an experimental initiative, the collaborative governance projects being studied share characteristics with sustainability experimentation projects. This is evident in their description of "policy analysis as a deliberative, action-oriented practice in which meanings and values are socially constructed" (Healey et al., 2003).

Table 1-1 Institutional Capacity Framework, Variable and Indicators

Source: Created by author, definitions from Spekkink 2015

IC Variables:	Definitions	Framework Indicators
Knowledge Resources	Capacity for collective action based on the quality of the knowledge and experience of the members of the community as well as the alignment of definitions of problems and solutions	Range of knowledge
		Frames of reference
		Integrating different spheres of policy
		Openness and learning
Relational Resources	Capacity for collective action based on the quality of the relationships of actors, such as the number and range of actors involved in the community as well as the level of trust between them	Range of stakeholders
		Morphology of social network
		Integration of various networks
		Power to act
Mobilization Capacity	Capacity for collective action based on the existence of a shared strategic vision and the presence of actors within the community that are willing and able to take the lead	Institutional arenas
		Opportunity structures
		Repertoires of mobilization
		Critical change agents

Boons et al., (2011) applied IC building to study the dynamics of industrial symbiosis, recognizing the need for a comprehensive framework to study the dynamics of IS development. At the time IS literature was in a somewhat similar state as current sustainability experimentation literature - there had been numerous theories studying microdynamics of IS from perspectives of innovation, geographic embeddedness, and social aspects, but there was limited comprehensive study of the dynamics by which actors built knowledge, social capital and mobilization capacity to actively enhance IS systems. The IC framework was applied as a way to study the overall institutional capacity needed for actors to collaboratively develop industrial symbiosis, using the analytical distinctions of knowledge resources, relational resources, and mobilisation capacity (Boons 2011, Boons and Spekkink 2012, Spekkink 2015).

Apart from physical constraints, developing IS for sustainability was constrained by two factors: "First, it is relatively easy to achieve superficial, short-term social changes, but social actors have a tendency to fall back into their old patterns of behaviour on the long term due to their embeddedness in an institutional context. Second, to ensure system change rather than system optimization, it needs to emerge from the existing system" (Boons 2011, Lambert and Boons 2002). This is similar to current sustainability experimentation literature, which find that experiments often fall short in establishing change beyond the experiment and increasingly focus on co-producing knowledge and change by engaging the actors embedded in the governance system.

IC building has since been applied to study IS network development in the Netherlands (Spekkink 2013, Spekkink 2015) and in China (Wang et al., 2017). Boons et al., (2011) found that the IC framework was well suited to understand the dynamics through which regional industrial systems develop in terms of actor connectivity and ecological impact by specifying

relationships between community development variables. Wang et al., (2017) highlighted the cross-cultural applicability of the IC building framework and found in their study that IC of an eco-industrial park network was increased by establishing relational links that actively included external actors with experience establishing similar projects.

Importantly, it appeared that IC building may contribute not just to the specific project at hand but may also develop broader system resilience and flexibility for actors to understand and plan for (or react) to evolving system dyanmics and potential issues. Similarly, Boons and Spekkink (2012) found that building IC extends beyond the original scope of action through creating new opportunity sets based on physical, institutional, or perception changes through the IC building process. For this reason it is suggested that the experiments studied in this research project are not just building capacity for the specific IS practice being tested but developing new sets of knowledge and working relationships geared towards sustainability.

Yet IC building is not a linear process, and the ability to shift focus from one specific project to broader network concerns happens over time (Spekkink 2013). A shared vision for collective action is built on trust through continued interactions and engagement. Actors with strong relationships are more likely to share and discuss knowledge or perspectives openly to find common ground (Spekkink 2015). However, it is not always necessary for actors to completely agree on an issue in order to work together. 'Knowledge inclusion' allows actors to mutually recognize differing perceptions among actors yet still see shared interests and opportunities for action (Spekkink 2015, Inness and Booher 1999). This can still result in a shared strategic vision that allows an opportunity set for actors, or at least allows potential facilitation by an intermediary actor (Spekkink 2015, Healey et al., 2003).

Significantly, IC is strongly related to embeddedness in the local contexts in which it is developed (Boons 2011, Wang et al., 2017). This is related to trust among actors and the ability to act within that community (mobilization capacity).

These studies also raised questions about the assumed positive relationship between levels of IC and increased action toward IS. For example, Boons and Spekkink also found that "of the three elements constituting institutional capacity, only the ability to mobilize actors crucial for the exchange shows up as a factor affecting the opportunity set of actors." This leaves questions about the actual impact of knowledge and relational resources without a clearly actionable opportunity set. However, the authors note this finding may be due to their focus on the Dutch context, where national support provided mobilization capacity not necessarily dependent on development of knowledge and relational resource development by network actors (Boons and Spekkink 2012).

Abreu and Ceglia (2018) recently examined the role of IC building through industrial symbiosis development in implementation of circular economy goals, using a case study of actors involved in the UK National Industrial Symbiosis Programme (NISP). This program was a government backed effort to facilitate industrial symbiosis coordination through building actor knowledge, partnerships and mobilization support. The study found that IC was increased among actors, and that the governmental role as a coordinating agency was key in facilitating knowledge and relational resources in a way that allowed direct action (Abreu and Ceglia 2018).

In terms of developing CE, it was found that the IC built through IS initiatives can directly support system transitions through new perceptions of waste solutions throughout the supply chain; expanded relational resources to include a broader range of stakeholders; and

higher mobilization capacity through increasingly shared problem definitions and opportunity sets, increasingly complex symbiotic exchanges, and economic feasibility (Abreu and Ceglia 2018).

2.3.2 Proposed Application of IC Building to Industrial Symbiosis Experimentation for CE developments

The IC building framework has been successfully used to comprehensively analyze social learning, network building, and direct action outcomes through its framework of knowledge resources, relational resources, and mobilization capacity. Additionally, it has shown that IC building has potential to prepare involved actors for not just the practice being implemented (such as waste exchanges), but also for identifying and creating further opportunity sets toward the goal of sustainability. The specific application to IS initiatives has also demonstrated that this IC building process can lay foundations for transition to a circular economy.

Given these findings, this research paper proposes and applies the IC building framework as a method to analyze sustainability experiments. Sustainability experimentation literature has identified gaps in ability to assess the quality of social learning taking place, the impact of the relationships developed, and the potential for the experiment to have broader impact.

The IC building analytical framework is applicable to experimentation research because its pillars and indicators are comprehensive of experimentation analysis topics and research gaps. For example, the 'knowledge resources' pillar and its indicators address experimentation topics of social learning. 'Relational resources' considers the experimentation and sustainability transition topics of actor networks, innovation networks, power dynamics, champions, frontrunners, and intermediary organizations. Mobilization capacity is the most important element, reflecting experimentation findings that learning and relationship building should not be the end goal of sustainability experimentation but a foundation for further action (Healey et al., 2003).

Further, literature has shown a need to examine the ways in which SMEs might adopt clean production or eco-innovation practices through organizational learning and external support for development of a CE (Dieleman 2007). Comprehensive research on IC building through experimentation can also support development of CE policy initiatives, as "passing from micro to macro level (organizational to system level) policies for CE, a wider body of knowledge is necessary and a stronger integration of different competencies is required" (Marra et al., 2018).

This research applies the IC building framework to two case studies of sustainability experimentation networks that were each designed to test a specific industrial symbiosis practice and influence broader awareness of CE practices for sustainability transitions.

For the framework to analyze emergent outcomes of multiple IS experiments as a whole, the institutional field of analysis is conceptualized at three levels.

The first level is the organizational level, at which individual actors (people or organizations) engage in the regional collaborative projects. At this level actors bring existing knowledge and perspectives, existing or potential relationships, and capacities for action that may develop further through the project.

The second level is that of the local or regional stakeholder level, which includes the various actors involved in the development of the sustainability experiment (in this case the symbiotic exchange project). Localized IC can be conceptualized at this level in terms of the knowledge resources, relational resources, and mobilization capacity of the actors in their local context. This essentially is measuring the outcomes of one specific collaborative sustainability experiment within the network.

The third level is the overall innovation network, including the various regionally bounded collaborations, through which the investigated practice has spread. At this level the actors are spread over a greater geographic area and linked within a broader network, potentially including greater knowledge and relational resources. It is at this level that mobilization capacity may reach a point that the overall innovation network may be able to influence external contexts for broader system transformation.

This thesis focuses on outcomes at the third level to determine whether the IC developed across the experiment network may lead to broader system impacts. That focus is informed by study of the organizational and regional levels which make up the overall network.

Institutional capacity building is considered a potential emergent outcome of the interactions that take place through individual interactions that lead to collective knowledge resources, relational resources, and mobilization capacity at the regional level. The strength of institutional capacity across the overall innovation network represents the network's interactions with external contexts affecting the innovation network, including economic, social, regulatory, and political contexts.

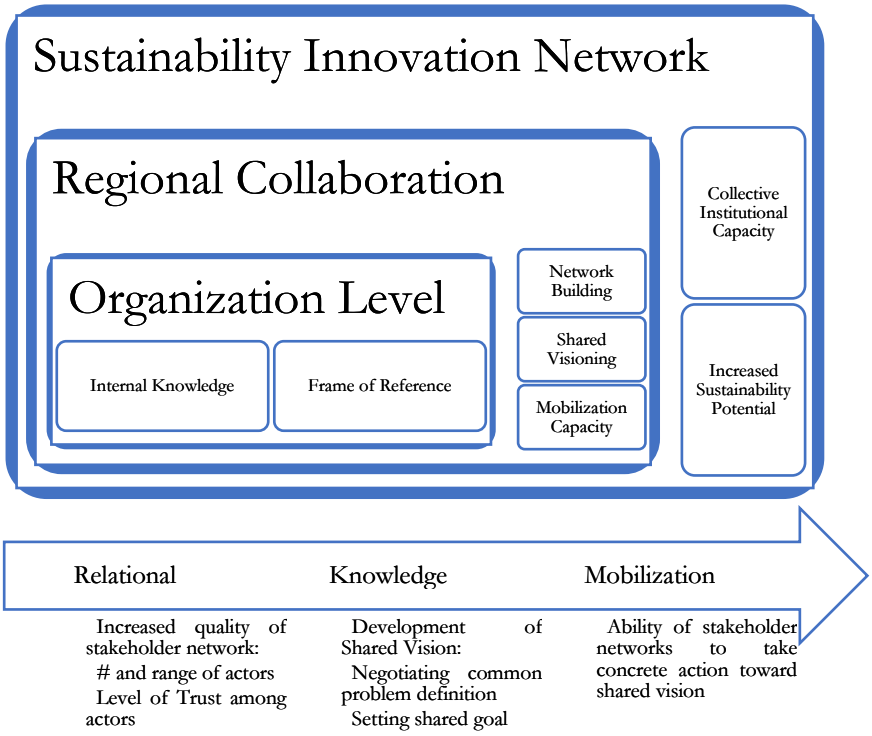

Figure 1-1 Institutional Capacity Building Across System Levels

Source: Created by author

2.4 The Craft Beer Sector

Beer production is one of the oldest industries in the world, likely emerging with the rise of grain cultivation and civilization in Mesopotamia (Li et al., 2017, Gibson and Newsham 2018). Beer is produced by converting grain starch into fermentable sugars, which yeast converts into alcohol during fermentation (Gibson and Newsham 2018). Beer can be made from any carbohydrate that converts into sugar, such as those from malted barley (most common), maize, rice, and wheat. The main ingredients in beer are a grain starch, yeast, hops and water (Li et al., 2017, Jennings et al., 2005). In times when the quality of water was often uncertain, beer was considered a safer alternative as the brewing process and alcohol product limit bacterial growth (Buiatti 2009).

The sociotechnical systems of beer production are also historically important culturally and politically (Jennings et al., 2005). In medieval and ancient times, preparation for feasts - considered important 'domains of political action' - required significant resources and labor to produce the required amounts of beer, meaning that management of beer production systems had significant political ramifications (Jennings et al., 2005). Beer brewing was also inextricably linked to bread baking, as they each used similar grains, water and yeast products (Buiatti 2009).

The process of beer brewing is fundamentally unchanged, but technological innovations such as the steam engine and refrigeration each each contributed to increasing mass production and distribution (Li et al., 2017). As of 2005, beer was the most consumed beverage globally behind water and tea (Nelson 2005, Patterson and Hoalst-Pullen 2014). Global beer production was transformed by mass consolidation of breweries and homogenization of beer types from about 1900 to 1980 (Garavaglia and Swinnen 2018). For example, from 1950 to 1980 the number of breweries in the UK dropped from 567 to 142, while in the USA it dropped from 358 to just 43 (Garavaglia and Swinnen 2018). However, this trend started to reverse with the global (re)emergence of small-scale 'craft brewing,' often attributed to the founding of New Albion Brewery in Sonoma, California in 1976 (Shears 2014). From 1990 to 2015, the number of breweries rose from 279 to 1,424 in the UK and from 270 to 3,500 in the USA (Garavaglia and Swinnen 2018).

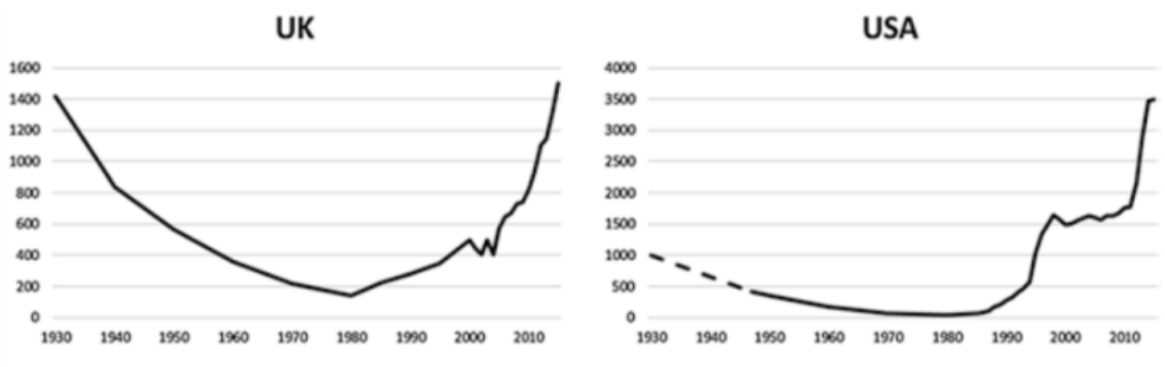

Figure 2-2 Number of breweries in the UK and USA, 1930-2015,

Source: Garavaglia and Swinnen 2018

The rise of craft breweries in the 1980s was driven by changing demands for more variety in beer styles, increasing incomes of beer consumers, and establishment of associations focused

on developing microbreweries (Garavaglia and Swinnen 2018). It is also characterized as a rejection of monopolization and the poor quality of mass-produced beer. Studies have recently adopted a 'place-based' perspective that explains the popularity of craft beer as resulting from increased interest in supporting local economies through local purchasing and a growing millennial market base interested in craft beer (Reid and Gatrell 2017). This trend is also a tangible representation of the re-emergence of 'craft' work, which in response to industrialization and mass-production "is seen to offer a wider range of human rewards in both acts of production and consumption… with food in particular paving the way for new debates about the relationships between producers and consumers" (Thurnell-Read 2014).

It should be noted that 'craft' beer is an ambiguous term in practice (Ness 2018, Garavaglia and Swinnen 2018, ch 1). The term is often applied to 'small' breweries who make a range of 'different' types of beer with attention to quality in the ingredients and brewing process, which contrasted the large breweries that mass-produced bland lager-style beers by replacing the malted barley with 'adjunct' starches such as corn or rice (Elzinga et al.,. 2018). Various definitions of craft refer to small breweries with limited production or a focus on 'traditional' or 'innovative' use of ingredients in the brewing process (as opposed to low-quality cost-cutting substitution ingredients). However, all definitions of craft beer face contextual challenges. Much of Europe has a deeply embedded history of local breweries and traditional beers, so 'craft' brewing can be split between re-emergence of traditional local breweries and breweries aiming to make innovative and experimental styles. As multinational brewing corporations have begun to produce beers of popular 'craft' styles, the focus has shifted from beer style to brewery size and independent ownership.

Beer production is very water and energy intensive and results in air emissions, wastewater and solid wastes (Hoalst-Pullen et al., 2014, Olajire 2012). Recent life-cycle assessments have shown that the beer production impact is relatively small in proportion to the environmental impact of packaging used and the growing, harvesting and transport of the malted barley (Hospido et al., 2005, Niero et al., 2017). Notably, global beer production is projected to decrease in the future due to extreme drought and heat impacts to barley production (Xie et al., 2018).

Many brewing companies are increasingly aware of climate and sustainability issues and are attempting to incorporate sustainability in their business practices (Hoalst-Pullen et al., 2014, Ness 2018). While craft beer SMEs are often considered more innovative and aware of sustainability issues than corporate breweries, major brewers typically have more funding to implement environmental management programs (Wells 2016). For example, large non-craft breweries have all conducted carbon footprint or greenhouse gas audits that many craft breweries have not, but craft breweries have closer connections to local communities and local economic development (Wells 2016, Ness 2018). Medium-sized 'regional breweries' may be the best positioned to make comprehensive sustainability decisions around sourcing, production and distribution as they are small enough to be agile in their decision making and supply chains yet large enough to benefit from economies of scale (Wells 2016, Hoalst-Pullen et al., 2014).

Recent studies have shown varied interpretations of sustainability within craft breweries (Hoalst-Pullen et al., 2014, Ness 2018). Many engage in operational resource efficiency measures or community engagement initiatives, though they often consider these to be differentiated goals (Ness 2018). Studies suggest that environmental initiatives are also being driven by the customer base, which engage with craft beer as an affectation of local craft

artisanship (Thurnell-Read 2014) and have demonstrated some willingness to pay more for sustainable beer (Carley and Yahng 2018).

Craft beer SMEs are responding to this consumer and governmenance-driven push for businesses to explicitly incorporate environmental and social benefits by working with stakeholders to maximize resource value and contribute to sustainable development goals (Geissdoerfer et al., 2017). While it is uncertain how these concepts may look in practice, craft breweries are among the businesses engaging in experimentation to identify types of environmental and social values that can be integrated into their operations (Huguenin and Jeannerat 2017, Bocken et al., 2018, Ness 2018).

Lastly, craft beer SMEs can also be considered a community institution in some cultural contexts. Recent academic literature has investigated perceptions of craft beer SMEs as locally embedded through creating a sense of place, providing a community space, and promoting local economic development and consumption (Schnell and Reese 2014, Fletchall 2016). Craft breweries have been particularly active in economic revitalization of old industrial neighborhoods and have even led to craft beer tourism in some cases (Reid and Gatrell 2017).

2.4.1 Sustainable Innovation Experiments in Craft Beer SMEs

Some craft breweries and community networks are utilizing creative sustainability innovations to integrate resource efficiency and social value into their organizational models in the form of circular economy experiments with explicit social learning goals. These innovative practices seek to utilize recovered materials as inputs to the brewing process or to find alternative uses to the byproducts of the brewing process (or both) in ways that may inspire new social conceptions of resource use norms in society.

While some circular practices are already common in the brewing industry, such using spent grains from brewing as animal feed, the waste hierarchy prioritizes the use of quality byproducts for human consumption to maintain higher resource value. Therefore, the circular practices described below can be considered 'upcycling' of products - finding higher utilizations of waste products to prevent inefficient disposal and new waste generation (Bocken et al., 2018). Prominent symbiosis and upcycling experiments include using unsold, surplus bread to offset a percentage of malted grain or using recycled water instead of freshwater in the brewing process. Conversely, the spent grain byproducts of brewing are being used as a resource for baked goods (including bread, granola, energy bars, etc.), though other byproduct uses include animal feed, compost and fertilizer.

These innovative forms of industrial symbiosis are mostly happening at the experimental phase, including as educational demonstration projects. Some craft beer SMEs are emerging as sustainability frontrunners by integrating these concepts into their business model permanently or developing partnerships for collaborative experimentation. These innovation experiments are mainly focused on social learning around sustainability and circular economy transitions, which may lead to increased sustainability awareness and action throughout the brewing sector. While these projects improve resource efficiency in operations, they are often developed more to raise community awareness of a specific sustainability issue such as food waste or clean water scarcity.

2.4.2 Case Study 1: Utilization of Surplus Bread in Beer Brewing

Craft Beer Sector in the UK

As local breweries and brewpubs are an element of traditional cultural heritage in the UK, the craft beer movement is split between tradition and innovation (Sandiford and Divers 2011, Cabras and Mount 2017). In 1900 there were 6,447 breweries that fell to 142 by 1980 due to increasing mass-production and consolidation (Cabras 2018). However, from 1980 to 2015 the number of breweries surged back to 1,500 and has now reached over 2,000 (Cabras 2018, Monaghan 2017). Unlike the American focus on new types of beer, this growth in the UK was driven by an increasing demand for traditional beers. The movement is typically attributed to the Campaign for Real Ale (CAMRA) association, which was a movement against industrialized mass-produced beer in favour of 'real ale' – beer brewerd with traditional methods that are not pasteurized or filtered, are stored in casks and served by hand pump (as opposed to highly carbonated keg beers) (Cabras 2018). This campaign was perceived as protecting the British heritage of real ales and aligned with growing support for protection of the traditional 'public houses' (pubs) as centers of community, particularly in rural towns (Sandiford and Divers 2011).

Further growth of microbreweries was sparked in 2002 with the introduction of the Progressive Beer Duty (PBD) which provided tax relief to support smaller brewers. This was led by campaigning from the Society of Independent Brewers (SIBA), which was founded in 1980 to promote craft beer and increase market share of craft brewers in the UK (Garaviglia and Swinnen 2018). The number of craft breweries continued to increase before stabilizing around 2016 with a newer generation of brewers and consumers driving interest in newer craft beer styles to supplement the traditional 'real ale' craft beer culture.

The relatively dense landscape of British breweries often position craft breweries in the regional context in a few ways. Microbreweries are considered to represent 'neo-localism' that creates a sense of place among its consumers, and such breweries often engage in local community events and festivals (Cabras 2018). UK microbreweries often face 'a spatially constrained supply chain' and small distribution networks, which supports the local integration of the microbrewery but limits scalability (Danson et al., 2015). Lastly, Cabras (2018) describes a craft beer environment characterized by collaboration and "a high exchange of information and… mutual support, which functions as an incubator for creativity and innovation with regard to brewing processes and recipes." This creates a welcoming environment for innovative brewing to complement the 'real ale' craft beer movement.

The Surplus Bread Brewing Experimentation Network

An emerging and spreading sustainability innovation is the recovery of surplus bread (unsoled or unused bread that would otherwise be discarded) to offset a percentage of grain used in the brewing process. This reduces the environmental footprint of the brewery and the bakeries by utilizing existing resources to reduce the need for new grains and limits disposal impacts of bread. Brewers have found that bread can replace about 30% of the fresh malted barley for optimum fermentable sugars.

Brewing with bread is not a new practice, but a restoration of an historic brewing technique. However, the idea for modern craft brewers to begin utilizing recovered bread started in Belgium in 2015. The Brussels Beer Project is a crowdfunded craft brewery with the mission to modernize Belgian beer culture from a focus on medieval, abbey style Belgian ales through brewing experimental and collaborative beers. They decided to simultaneously experiment with circular economy practices and pay homage to ancient mesopotamian brewing practices by using unsold fresh bread in the recipe with their release of the Babylone beer.

That project caught the attention of two food waste activists and organizers in the UK, where over 40% of bread is wasted (Tesco and Society 2014). Seeing potential for using craft beer to raise awareness of food waste through a tangible upcycling project, in 2014 they founded a social enterprise brewery (Brewery 1) that brews a range of beer with surplus bread from a large sandwich producer, with profits going to a food waste-focused NGO. However, a large focus of theirs is initiating collaboration brewing projects with other craft breweries to raise awareness about the food waste issue and the potential use for unsold bread in beer. Each collaboration project entails arranging delivery of surplus bread from a local baker to the brewery for a single release beer with proceeds directed to a local charity. They have partnered with over 20 breweries in the UK and have begun to spread their business and collaboration network to other countries including the US, South Africa, Ireland, Brazil, and Iceland.

Separately, several other breweries have begun using the practice. Founded in 2017, Brewery 2 brews a full range of beer with surplus bread in partnership with a local baker. They also contract out brewing but distribute on a much more regional level. Brewery 3 is a community brewery that has done a single release bread brewing project with their local baker but is planning to integrate the practice consistently when they both move to a new shared facility with their local baker. The baker already makes bread with their stout ales and they plan to implement more symbiotic practices in the shared facility. This brewery is actively involved in the sustainability transition movement of their town and will be issuing community ownership shares to help fund the new facilility. Brewery 4 is a small craft brewery that conducted an initial surplus bread brewing experimentation process and single release beer with support of a Zero Waste Scotland (ZWS) program aimed at developing CE initiatives in SMEs. After this initial pilot, they continued the relationship with the baker and have added that surplus bread beer to their core range of beers, and plan to add one more soon. Other breweries have experimented with the practice for single release beers.

The way in which this practice has grown amongst a community of brewers through successive collaboration projects shows characteristics of an iterative, distributed experimentation process for sustainability innovation. The brewers, bakers, and others who have supported this niche practice function as an experimental network to test and learn about this industrial symbiosis practice which could provide a valuable use for bread waste, reduce fresh grain inputs in beer, and raise awareness among brewers and consumers about sustainability issues and the potential for breweries to consider sustainability in their products and operations.

2.4.3 Case Study 2: Demonstrating Recycled Water for Human Consumption through Craft Beer

Craft Beer Sector in the US

The American craft beer movement began in 1965, when the the Anchor Brewing Company in San Francisco was bought and revitalized to begin brewing traditional all-malt beers. The US beer market at the time was characterized by a few massive beer corporations producing light lager style beers with 'adjunct' ingredients such as rice or corn as a cheaper source of fermentable sugar than the conventional malted barley. In 1977 the New Albion Brewing Company was founded as an independent local brewery in California, catalysing the emergence of the American craft beer revolution.

Craft breweries were a niche concept that eventually grew due to key events including the legalization of homebrewing, a federal tax reduction for small breweries, state legalization of

brewpubs, and shifting market demands for craft beer (Elzinga et al., 2018). At the same time, economic and technological factors were driving consolidation of macrobreweries, which declined from 421 in 1947 to just 10 in 2014 (Elzinga 2015, Elzinga et al., 2018). In 1985 the number of craft breweries in the US (37) surpassed the number of macrobreweries (35), followed by an explosive growth that temporarily stabilized around 1,500 craft brewers in the year 2000 (Elzinga 2015). The US Brewers Association statistics show another period of explosive growth from 1,800 craft breweries in 2010 to 7,450 craft breweries in 2018 (BA 2019). Though the number of new craft breweries is again stabilizing, the market share of craft beer is growing – from just 0.1% of the US market share in 1986 to over 12% by 2015 (Elzinga et al., 2018, Reid and Gatrell 2017). The BA states that the craft brewing industry contributed $76.2 billion to the US economy in 2017 (BA 2019).

The Experimentation Network

As freshwater resources grow strained, some water and wastewater utilities are partnering with brewers (home brewers and craft beer SMEs) to demonstrate the usability of recycled water, which has been treated to meet or exceed drinking water standards, by providing advanced treated water for organized brewing projects. Brewing beer is a very water-intensive process and replacing fresh water with recycled water can offset much of this impact. However, the goal of these projects is largely educational, acting as a demonstration of the high quality of recycled water to raise awareness about water sustainability and the likelihood of needing to use recycled water more frequently in the near future.

The development and proliferation of recycled water brewing projects has emerged mostly in the arid American West, though there are examples throughout the United States. This practice emerged in 2014 at Clean Water Services (CWS), a water utility in Oregon that organized a competition for home brewers to brew beer with recycled water. The competition model has been repeated throughout the innovation network as a means of engaging brewers and testing public perception and readiness for consumption of recycled water. As recycling water requires more financial and technical resources than brewing with recovered bread, the innovation network around this practice involves a broader range of actors including brewers, water utility companies, engineering and technology firms, and water related nonprofits to develop collaborative experiments.

Initial projects provided the treated water to homebrew association members in a competition style project to incentivize participation and build excitement. Homebrewers were used initially because of regulatory barriers to providing licensed commercial brewers with recycled water for human consumption. However, as these competitions and collaborative demonstrations have raised awareness for the practice, within the water industry and in public perception, regulators have worked with recycled water networks to allow increasing levels of permitting, ranging from one-time educational permits to fully permitted direct potable reuse.

This growth has also shown the characteristics of a distributed experimentation network. The CWS competition has become an annual event that has grown in popularity each year. After seeing the winning entries from CWS showcased at a water reuse symposium in 2015, the Hillsborough County Public Utilities decided to hold a similar project before hosting the symposium in Florida. More utilities across the US have held similar demonstrations of recycled water in brewing, both with homebrewers and increasingly with commercial craft breweries as the practice becomes more accepted and receives exploratory regulatory permitting. Other projects have been held in arid states such as Colorado, Idaho, and

California, with the largest to date being a state-wide craft brewery competition in Arizona. This competition engaged over 25 commercial breweries in using recycled water, resulted in the first permitted treatment sites for human consumption, and funded a mobile purification facility that was later used to demonstrate the practice to other states who are interested in exploring recycled water.

The spread of this practice has included deliberate knowledge and technology sharing among partners interested in similar projects. This has even led to the development of formal innovation networks with the goal of sharing knowledge of the practice and supporting further awareness and use of recycled water.

3 Research Design and Methodology

This research uses an inductive case-based research approach using a sample of two cases (n=2). As described by Perry and Bellamy (2011), case-based research is appropriate for in-depth analysis of a small number of cases to investigate and consider case factors such as chronology, context, and interactions between variables in search of causal processes and emergent outcomes. This approach allows a range of methods to include diverse qualitative data can allow for an "iterative dialogue between theory and empirical evidence" (Perry and Bellamy 2011). The research methodology is informed by literature review of experimentation and transition literature, which informed the steps of identifying experiment network case studies and developing a project scope and research plan.

3.1 Research Methods

This research project was conducted in a multi-phase process consisting of initial literature review to inform the choice of an analytical framework for experimentation analysis and the selection of two case studies of bounded experimentation networks. After further academic and grey literature review, key actors within the two experimentation networks were contacted for semi-structured interviews. These interviews took place in person and by webcall during March and April 2019.

The initial literature review included broad examination of peer-reviewed literature related to sustainability transitions, experimentation, transition governance, social learning, actor networks, circular economy, industrial symbiosis, and institutional capacity.

For empirical research, interview questionnaire templates were designed to solicit specific answers related to the dynamics and outcomes of the sustainability experiment network. The semi-structured interview format allowed for some flexibility to customize interview questionnaires to an actor or follow up on topics raised in the interviews. The interviews were designed to provide insight on the interactions that led to regional collaborative projects, how knowledge and relational resources were developed, and whether this has led to increased mobilization capacity across the regional level innovation networks.

3.2 Case Studies

Background information on the two case studies selected is given in section 2.4.2 and 2.4.3 respectively. The two craft beer innovation networks chosen for analysis were selected based on multiple characteristics, including:

- experimentation with an innovative sustainability practice requiring industrial symbiosis activities (and thus the engagement of multisectoral actors collectively retaining resource values);
- a clearly identifiable emerging network of practitioners conducting successive experiments, which suggest some level of knowledge sharing and network building to be analyzed
- and multidimensional social learning aimed at the participating organizations and the general public

For each case study, these characteristics are examined and presented in detail to inform analysis of IC development.

These specific cases were also selected because of the considerable attention they were receiving in global media. Though each network of users is fairly small, their choice to

use beer as a demonstration of circular economy concepts created a lot of media coverage about the unique, innovative sustainability practices of diverting surplus bread to beer brewing to fight food waste and of using recycled water to brew beer. Certain actors within each case have also won awards related to work on sustainable development goals, for transformational innovation, and other recognitions of sustainability transition potential.

3.3 Analytical Framework

The analytical framework being applied in this study is the institutional capacity (IC) building framework, introduced in section 2. This framework will be used to analyze the overall IC built in each emerging network of sustainability experimentation.

Recent experimentation literature has investigated questions of social learning, network building, and how to harness these for sustainability transitions, but has been missing a way to comprehensively assess these dynamics. The IC pillars of knowledge resources, relational resources, and mobilization capacity provide an analytical lens designed to consider whether a group of actors have sufficient knowledge and relational resources to continue developing and scaling the experiment subject, therefore fitting research needs in experimentation literature.

3.4 Methods for Data Collection

3.4.1 Primary Data: Participant Interviews

To investigate the case studies beyond the information available online, semi-structured interviews were conducted with representatives of organizations participating in these collaborative experiments, including breweries, community organizations, government agencies, and other identified key actors. Interviews took place in-person when possible in the UK, and by webcall in the United States.

Interview questionnaires were designed to examine specific research questions but flexibly enough for interviewees to provide new information and their own perspectives on the topic. The organizations interviewed are listed below.

The names of specific breweries and their representatives are kept anonymous to prevent this report from being promotional. The names of public agencies are used, though the names of the actors interviewed are not.

From the surplus bread brewing network, thirteen interviews were conducted with actors representing eleven organizations in the network. All of these were craft beer SMEs except for an interview with ZWS, who supported a bread brewing experiment.

From the recycled water brewing network, interviews were conducted with eleven actors from different organizations. This included six breweries, three wastewater utilities, and two non-profit organizations involved the experimentation network.

Table 3-1 Case Study 1; Stakeholder Interviews from Recovered Bread Network

Source: Created by author

Organization Interviewed	Involvement in Experimentation Network
Brewery #1	Social enterprise brewery founded by food waste activist; contract brews a full range of beers brewed with surplus bread; initiates collaboration brewing projects with other craft breweries using recovered bread
Brewery #2	Craft brewery; contract brews range of surplus bread beers in partnership with local bakery
Brewery #3	Community brewery; participated in collaboration with Brewery #1; currently building shared facility with local baker for collaborative production
Brewery #4	Craft brewery; participated in bread brewing experiment facilitated by Zero Waste Scotland, which resulted in one surplus bread beer being added to the core range with another planned in the future
Brewery #5	Participated in one of the first collaboration projects with Brewery #1 to test brewing with bread; project received national media attention
Brewery #6	Participated in early collaborations with Brewery #1 to test brewing with bread; have done multiple repeat collaborations
Brewery #7	Community brewery being launched with support from local transition initiatives; plans to brew with surplus bread from local baker (not yet active)
Brewery #8	Craft brewery; multiple surplus bread collaborations with Brewery #1
Brewery #9	Organic craft brewery; multiple collaborations with brewery #1
Brewery #10	Craft brewery; partnered with Brewery #1 for bread brew
Zero Waste Scotland	Supported bread brewing pilot project as part of SME circular economy support services

Table 3-2 Case Study 2; Stakeholder Interviews from Recycled Water Network

Source: Created by author

Organization Interviewed	Involvement in Experimentation Network
Clean Water Services	Organized first recycled water brewing competition in 2014, annual competitions have grown and are now permitted to engage commercial breweries for educational purposes
Oregon Brew Crew	Homebrew organization that helped organize and supplied brewers for Pure Water Brewing competitions
Hillsborough County	Organized recycled water homebrew competition for WateReuse symposium in Tampa; partnering with commercial brewer for education plan
Pima County WWRD	Organized first commercial scale recycled water brewing competition with 26 breweries in Arizona; built mobile purification facility to spread practice
Brewery #12	Participated in AZ Pure Water Brew competition
Brewery #13	Participated in AZ Pure Water Brew competition
Brewery #14	Participated in AZ Pure Water Brew competition
Water Now Alliance	NGO promoting sustainable water use among local goverments; supported AZ Pure Water Brew competition

Water Environment Federation / Pure Water Brewing Alliance	Not-for-profit training and education association for water quality professionals; provided platform for Pure Water Brewing Alliance
Brewery #15	Participated in Boise, Idaho recycled water brewing demonstration
Brewery #16	Participated in Boise, Idaho recycled water brewing demonstration
Brewery #17	Conducted recycled water brewing demonstration for California Craft Beer Festival

3.4.2 Secondary Data: Literature Review

The data collection from literature review consisted of online searches of academic literature databases for peer-reviewed academic articles and search engines for online news articles and brewery websites related to the key searches. As initial research led to the research questions and aims, the identified topics and frameworks were used in a literature review matrix to collect and organize data from the literature review.

3.5 Data Analysis

Data analysis for this project was conducted through a combination of the qualitative data analysis program NVivo 12 and spreadsheets to organize and analyze data findings. Within the NVivo program, a case file was created for each selected interviewee organization and their collaborative project. All data relevant to the project, such as interview notes or transcripts, web pages, and news articles, was then tagged to the appropriate case file.

Once the primary case boundaries were identified, all academic and grey literature relevant to the study was collected in NVivo. Within this program, the literature was reviewed and relevant sections were coded to a "node" representing a specific topic of the literature review or element of the analysis framework. For example, literature text related to social learning through experimentation would be coded to the nodes 'social learning,' 'experimentation,' but also the relevant framework nodes of 'knowledge resources.' This coding of literature allowed management and analysis of literature topics to inform the overall literature review section, development of the conceptual framework indicators, and subsequent interview questionnaires.

After conducting the semi-structured interviews with organizations, interview notes and transcripts were also analyzed in NVivo. These were all reviewed and coded initially to the framework indicators of institutional capacity as described earlier. These findings were compiled and analyzed to assess the levels of institutional capacity at the innovation network level.

After data coding was conducted, all findings were reviewed and analyzed in terms of the framework and literature review to inform the discussion section.

3.6 Research Limitations

This research has taken all possible steps to ensure research validity. Semi-structured interviews have been supported with extensive grey literature and academic literature review to contextualize findings and present an unbiased assessment. From each network, a strong sample size of 10+ actors has been selected to give diverse perspectives on actor experiences and outcomes. However, there are some possible research limitations.

First, the interviewees who were interested in participating in this research project may not be representative of the network as a whole. Though many actors were contacted for interviews, those who agreed to participate were often the actors most engaged in their experimentation projects and networks as well. This suggests that they may have a different level of engagement, awareness, and perception of the projects in terms of CE and sustainability implications than other actors who were less involved and may have participated for other reasons. However, the stakeholders interviewed provided somewhat diverse opinions and responses, indicating this sample is indicative of of the range of perspectives that network actors may hold.

Second, the experiments studies are testing relatively simple symbiotic resource exchanges and short-term projects. Though collaborative experimentation is seen as a way for stakeholders to negotiate personal interests and perspectives to develop a shared vision, some of the projects studied may not have required high enough commitment or engagement for actors to truly examine their final goals or personal sustainability practices. Yet as an initial test of IC building to test collaborative experimentation, the research still provides sufficient diversity of project types and detailed interview responses to shed light on this issue.

Lastly, the rapid emergence of the experiments shows promising growth of the experimentation network but may provide a relatively short time period from which to analyse the collective outcomes of the experimentation networks. This research provides legitimate analysis of the knowledge resources, relational resources, and mobilization capacity developed by actors but assessing the true impact will require further study over longer periods of time to determine the actual impacts of the capacity developed.

4 Findings

4.1 Surplus Bread Brewing Network in the United Kingdom

4.1.1 Relational Resources

4.1.1.1 Range of Stakeholders

Since the practice of experimenting with surplus bread brewing began in the UK in 2016, the range of stakeholders involved in this process has grown substantially. Over 30 craft breweries have brewed with bread, mostly as one-time promotional projects. Much of this growth has been driven by a social enterprise brewery (Brewery 1) which contract brews bread beer for their own range of beers and engages other craft breweries for collaboration beer projects utilizing leftover bread. Their business model is based on advertising the sustainability of their beer through fighting food waste. Brewery 1 has directly engaged over 20 craft breweries in bread brewing projects, generally consisting of a planned partnership to provide the brewer with unsold bread from a local baker and to direct the proceeds to a local charity.

Most of the breweries participating in these projects are small craft breweries, though some of the projects are done with individual branches of a franchise chain of brewpubs where the head brewer has freedom to experiment. Of the breweries interviewed, three said they would be willing to participate again but did not have any concrete plans, four had done (or were in the midst of) repeat collaborations on new bread brews, and four said they were not planning to do such a project again. Additional collaborations are being tested and planned with larger breweries as well to expand the involved stakeholder range to include actors who are generally more traditional and less experimental.

However, of all the breweries who have experimented with bread brews there are only two that have integrated recovered bread as an ingredient in their full product range. As mentioned, Brewery 1 is a social enterprise brewery with all profits going to a food waste reduction charity. The bread for their core range of beers is sourced from a large-scale ready-made sandwich manufacturer in the UK, who donates the end slices of bread loaves that are not used in sandwich production. The second full time bread brewery (Brewery 2) is a small, recently established craft brewery partnered with a local artisanal baker to supply leftover bread. They are both contract brewers, meaning they contract with an existing brewery to brew and bottle the beer for them at their facilities.

Two more breweries are planning to incorporate bread brewing into their full range of products. One is an established brewery that has done an initial bread brewing collaboration (separate from the Brewery 1 collaboration projects) and is planning to adopt the practice further as they move to a shared space with their local baker in the near future. The other is not yet established but has done a soft launch (one initial batch released at a local festival) and is planning to brew a full range of bread beers when they go to market. Both breweries are planning to sell ownership shares to crowdfund their brewing facility projects and become community owned breweries.

A fifth brewery that experimented with bread brewing, through a collaboration project facilitated by Zero Waste Scotland (ZWS), continued their partnership with the local baker to establish one full time bread beer and is planning to launch a second full time bread beer

soon (within their broader range of beers). ZWS remains engaged with this brewery to continue supporting resource efficiency projects through SME support programs.

This range of stakeholders represents the craft beer enterprises, and the associated bakers and NGOs, that are involved with experimenting with and pioneering surplus bread brewing in the UK, which was the scope of the studied network. The network has begun to grow beyond this boundary as well through direct collaborations initiated by Brewery 1 (notably with projects done in the United States, Iceland, Ireland, Brazil, Sweden and South Africa). Others have conducted similar educational one-time bread beers in these countries, Canada, Belgium as noted, and elsewhere.

4.1.1.2 Morphology of Social Network

As this experimentation network has grown, the morphology of the social network of stakeholders has increased in breadth but is spread fairly thin over a wide geographic range with loose connectivity. Many of the regional systems behind each bread brewing project consist of a locally clustered brewery, bakery and charity. Most of the actors involved are directly connected to Brewery 1 as the catalyst and facilitator of the individual collaboration brews. In this way, the morphology appears as a group of 20 regional system clusters of actors tied back to one main actor. There are three exceptions where regional clusters have no direct connection to Brewery 1, but the actors there have working relationships with other brewers in the network and are aware of Brewery 1's work.

Each of the breweries using bread full time also have their own small ecosystems of actors within the larger network. For the range of beers Brewery 1 produces as their main product, this includes strong business and logistical connections with the industrial sandwich producer that provides surplus bread, the contract brewer who receives and brews with the bread, a growing distribution network where their beers are stocked, and the nonprofit food waste charity which receives the proceeds of their sales and collaborations. Their direct network is also growing upwards and outwards as they begin partnering with larger established breweries in the UK and developing collaborations internationally. This is similar for Brewery 2, the other full time bread brewer, whose direct network consists of the artisanal baker which sources their bread and sells their beers, the brewery they contract with (located outside the immediate region), and the consultants they engaged to refine their product.

The breweries planning to issue community ownership shares and implement a full range of surplus bread beers also have a dense cluster of local stakeholders. As community-based enterprises, they are supported and influenced by a diverse range of actors. For the existing brewery (Brewery 7), this includes a board of directors with personal and organizational ties to local pub and hospitality industries, the town's sustainability transition network, environmental journalism and more. The brewery that is yet to launch has about 20 founding members representing local interests including people involved in a local social enterprise development organization (that is also managing the grant funding program supporting the launch), renewable energy organizations, urban agriculture and food advocates, local music and cultural movements, and other social groups.

4.1.1.3 Integration of Various Networks

It appears that the growth of the bread brewing innovation network is partially overlaid on an existing informal network of craft brewers. Interviewees indicated that the UK craft beer community is small and tightly knit, with many brewers who know each other through prior work experiences or collaborations, attending the same beer events, festivals or workshops, or through mutual connections. The trend of craft brewery collaborations and experimental

beers was often cited as a characteristic of the craft beer industry that suggested openness to testing new practices and a high number of existing partnerships within the sector. Some of these relationships were utilized for knowledge sharing for this innovation network.

In a few cases the brewers who worked with Brewery 1 in their early stages to test and refine the bread brewing practice were available as contacts for other brewers considering doing a bread beer collaboration themselves to discuss and give technical advice on the practice. In other cases, brewers expressed they reached out to other brewers on their own to ask about the practice. This informal network of brewers adds a light web-like nature to the actor network, as a broad array of actors working with Brewery 1 can connect with each other for discussions.

Within the informal network of craft beer SMEs in the UK, there appears to be an even smaller network of actors who are frontrunners in sustainability practices or environmental performances. Interview questions about networks or resources to support sustainability in breweries revealed that most interviewees felt that no such network existed in any formal sense, but often referenced the informal knowledge sharing that happens among brewers. This small group of actors often referenced each others' work and learning during interviews, highlighting a degree of openness and connectivity between this group of like-minded actors. Some actors pointed to the national Society of Independent Brewers (SIBA) as a membership association supporting independent traditional and craft brewers but mentioned this was more of a market advocacy group than a direct support network, with limited sustainability focus.

The involvement of local charities and bakeries seemed to hold potential for network integration at the regional system scale, but most relationships developed there were temporary connections and not sustained in most cases. However, there are instances of deeper integration where breweries have aligned their business with a social or environmental cause. For example, the only organic beer brewer to participate in these bread brewing collaborations is also a member of the Soil Association, UK's organic certification body, and an insect biodiversity organization that helped facilitate the bread brewing collaboration between them and Brewery 1. Further, their focus on organic and local agriculture entails a relationship with their local organic barley grower and malter, as well as the farm which receives spent grain for animal feed.

The organic brewery and Brewery 1 are also the two certified B Corps in the bread brewing network. B Corp certifies businesses for certain social and environmental performance standards. This represents another network providing resources, assessment and certification for businesses to utilize their business model to contribute to sustainable communities and responsible business environments, with increasing reach to the craft beer sector.

4.1.1.4 Power to Act

As with other industrial symbiosis resource connections, brewing beer with surplus bread requires cooperation of at least two organizational actors to ensure a supply of 'waste' bread from bakers to brewers. Interviewees claim that so far nobody has run into any issues finding surplus bread to use, given that part of the appeal of this practice was creating value out of the enormous amounts of bread that is wasted daily in the UK. While the breweries producing exclusively bread beers were able to develop strong working relationships through direct discussions, most of breweries doing single release collaborations were connected to a baker by a facilitating actor.

Most interviewees expressed that it would be difficult logistically to continue the practice on their own. Challenges include supply chain logistics of how to collect, store and deliver fresh surplus bread in a timely manner for the brew process. This is especially true for small breweries and bakeries that may not have enough storage space. One interviewee also expressed that brewers and bakers generally operate on very different schedules. Bakers tend to operate mainly in the morning hours and send delivery trucks out early in the day, whereas some smaller breweries won't open or begin brewing until later in the day.

For any of the individual collaboration projects, this logistical barrier is overcome by the facilitating organization. For example, when Brewery 1 organizes a collaboration brew, they must make it as easy as possible for the brewer to participate by identifying bakers willing to donate surplus bread and arranging the logistics of collecting and delivering the bread. This means that for the brewer, they just need to decide the type of brew, schedule a brew day and wait for the bread to arrive.

However, a bigger issue with bread brewing is that brewers find it does makes for a harder brewing process. Even brewers who enjoyed their projects describe the process as more time consuming and logistically challenging than using conventional malted barley. The extra steps of shredding the bread, boiling it to release sugars, and mixing with the rest of the mash add steps and time that small breweries may be unwilling to take outside of these occasional collaboration projects.

4.1.2 Knowledge Resources

4.1.2.1 Range of Knowledge

Various types of practical and conceptual knowledge are required to facilitate and implement the utilization of surplus bread as a material stream for beer. The existing knowledge held by craft beer SMEs includes the logistics of running a brewery, including selecting and sourcing ingredients, creating quality products, product distribution and sales, and waste disposal. Similarly, to incorporate surplus bread requires bakers who understand the bread distribution systems and handling of surplus. To connect the two industries required building understanding of what both actors need, in terms of desirable bread products and collection, storage, and distribution timing, and how to facilitate that.

While these types of knowledge are seemingly inherent in the existing business of the breweries and bakeries, developing symbiotic resource projects and facilitating collaborative experimentation required broader types of conceptual knowledge and openness to change. The innovation of diverting recovered bread to beer was catalyzed by actors who understood the negative impacts of food waste and the circular economy principles that allow surplus bread to be viewed not as a waste but a valued material.

There was a shared understanding among all interviewees that brewing beer with recovered bread is only feasible if there is a market for it. Many brewers considered their local customer base to be aware of environmental issues and found they were interested in the story of fighting food waste through good beer.

Yet even when geared toward an experimental craft beer audience, the knowledge of how to market products and influence public perception is even more important than the ability to make the beer. This requires actionable knowledge and experience in marketing and public relations. Several of the brewers interviewed expressed that marketing and promotion were not their strong suit but acknowledged the importance of this for their SMEs to be

successful. Because of this limited PR capacity, interviewees found value in the branding and story-telling experience that Brewery 1 brought to the table during partnerships. The marketing knowledge and resources helped to promote and sell the beer itself, to tell the story of fighting food waste through beer, and to provide brand recognition for the participating brewery as well. Various interviewees cited specific instances of customers claiming they found the brewery through news articles or social media covering the surplus bread brewing projects.

4.1.2.2 Frames of Reference

The main frame of reference informing this practice, at least for most of the champions and frontrunners of the practice, is the idea that the negative problems of food waste can be minimized and the value of surplus food products can be maintained at a higher use than animal feed, compost, or landfilling. However, there are varying opinions on how these bread beer projects can meet that goal. Some interviewees considered this to be more of an awareness raising exercise than a long-term solution, using single release bread beers to tell the story of how much good quality bread is being wasted.

Through the collaboration projects many actors came to realize the scale of wasted bread as a potentially available source of ingredients that can be made available to brewers at no- or low-cost. Some interviewees expressed this could only be done full time on a small scale with breweries and their local bakeries. This was informed by a perception that good beer should be made with good bread.

One brewer interviewed specifically criticized the bread culture of the UK, claiming that they wouldn't want to brew beer with the bread found in supermarkets that makes up much of the waste stream. Conversely, other interviewees thought the practice was better suited to large industrial brewers for the same reason. Since much bread waste happens on the production side, these interviewees thought this consistent supply of mediocre bread could provide a steady resource for the beer produced by large industrial brewers, in the same way that rice and corn are used as an adjunct source of starch to supplement the malted barley to cut costs.

Though many actors suggested the practice might be scalable within the beer industry, just five of the interviewees expressed plans or interest to adopt the practice full time. Even among these actors, only two wanted to position sustainability and fighting food waste as the main message behind their beer so that consumers can feel like they are supporting a good cause through choosing that beer. The other interviewees thought that the best way to conduct and communicate the practice was to present the bread as a valuable and quality ingredient in the beer that can provide co-marketing benefits to the bakery and brewery involved. The idea supporting this was that fighting food waste and recovering surplus bread was a positive story behind the beer, but that the best way to gain traction with consumers was to emphasize the quality of the product over the sustainability message so that drinkers mentally choose it for taste rather than 'to do good.' Yet they did acknowledge that communicating environmental practices provides a helpful element of brand differentiation in a saturated craft beer market.

Among the collaboration breweries, there were various frames of reference that motivated their participation. The main factors included potential co-marketing benefits, a chance to brew an "environmentally friendly" beer, inherent curiosity and interest in experimenting with new beer styles, and to raise funds for charitable causes. While many interviewees cited

all of these factors, co-marketing and collaboration motivations were mentioned more frequently than the inherent motivation to address environmental issues.

4.1.2.3 Integration of Different Spheres

According to most interviewees, the collaboration partnerships went smoothly and actors felt that stakeholder perspectives were mostly aligned. Most brewers said the project was as easy as any normal collaboration project, and that the process of brewing with surplus bread wasn't challenged by an insufficient range of knowledge or conflicting frames of reference.

While actors cited different motivations for participating or different perspectives of the food waste problem and potential solutions, these perspectives were generally not challenged or negotiated in the process of individual collaboration projects. In a few instances interviewees cited potential difficulties with the number of actors involved and the way the beer is branded. As one respondent elaborated, there are only so many logos that can fit on a bottle, and one brand name is going to be before the other. However, this is a challenge inherent to collaborations anyway and not specific to this type of project.

The community owned breweries had slightly more challenges integrating actor perspectives for a shared vision. One interviewee explained that most challenges didn't arise from overly conflicting perspectives, but simply from the inherent challenges in launching a collaborative project of any kind. Yet a few respondents noted that things could get confusing with so many actors contributing ideas of how to operationalize their visions for the brewery and highlighted the benefit of organizational leadership to help align perspectives and actions.

There were also some difficulties integrating types of knowledge and perspectives for the breweries who contracted out the brewing of their range of bread beers. Brewery 2 discussed how the search for a contract brewer was more difficult than had been expected due to skepticism from brewers about the process of brewing with bread. They thought this might partially be due to the nature of brewers who have facilities big enough to contract brewing and bottling for other brands. This type of brewery operation is typically run by slightly bigger brewers who aim for operational and ingredient consistency, as brewing a full range of beers over time requires a more consistent product than single release experiment beers. However, Brewery 2 was able to provide legitimacy for the practice by hiring respected industry consultants to develop the product range and test the optimal bread ratios to use for maximizing fermentable sugars.

4.1.2.4 Openness and Learning

Overall, interviewees portrayed craft beer SMEs as inherently experimental and collaborative. This seems to be supported by the interviews with brewers, whose creativity and experimental nature were evident in some of the styles of bread beers made through collaborations. These included efforts to play with the bread theme in ways like adding banana to give a banana bread taste, using currants and cinnamon for a "bread pudding" dessert beer, and other creative uses and names for their experimental beers. Brewers thought this showed how they were embracing the practice and happy to highlight the bread ingredient. The openness to experimentation was also demonstrated by interviewee stories of other experimental beers with recovered ingredients, such as coffee stouts utilizing used coffee grains, fruit beers with left over fruit from juice companies, mushroom stouts using mushrooms grown from spent brewing grains, and other fun demonstrations of circularity.

However, these brewers also understood why others would be unwilling or unable to try brewing with bread, ranging from pure disinterest to limited capacity for SMEs to engage in

activities not efficiently driving their core business product. Many interviewers expressed that the learning process to brew with bread is arduous, messy and significantly different in practice than other projects which might just add a supplemental ingredient but don't alter the brewing process like integrating 20-30% bread does.

Even after refining their methods, bread brewing makes for a more complicated process. For the more creative brewers this can provide an opportunity for public engagement, as one says they invite people from their community to participate in the brew day by helping tear up bread and contributing to the brew process. While participating they are educated on food waste, the fermentation processes, and how brewers operate. The interviewee says this maximizes the communal fun and learning from this collaboration project, but that bread brewing would still be too difficult to implement full time in their small brewery.

As for openness to new practices, brewers explained that experimenting with supplemental ingredients is very different than experimenting with core ingredients or operational processes that may affect the final product. The top concerns of all brewers interviewed, especially when discussing their core range of beers, was a consistent, high-quality product that the consumers would enjoy. Any motivation to change the recipe or process is generally motivated toward improving beer flavor, and they would be unwilling to make changes that pose risk of negatively impacting the flavor. A concern with bread is that they cannot control the consistency or flavor of the bread's contribution to their malt profile and therefore see it as a potential hindrance to the creative process and consistency of the beers they are making. Therefore, many claimed they would be unlikely to adopt the practice full time as they thought it would make their main goal - brewing good beer consistently - more difficult to achieve. The full time bread brewers have managed to align their core beers with a consistent supply of a specific type of bread, but this is dependent on a steady supply of the same bread.

One potentially limiting factor to the openness and learning capacity of craft brewery SMEs in the UK is the dynamic among "craft" breweries and pubs straddling the newer craft culture, largely characterized by new world beer styles, and the traditional "real ale" movement in the UK. This movement is also emphasizing a return from industrial brewers to localized breweries but does so in a way that returns to historically traditional styles of beer and beer making consisting of live cask ales and limited ranges of style. Interviewees expressed that these brewers, though also interested in the local element of the brewery and potential for local partnerships, are generally less open to experimental beer styles or newer processes.

However, both organizations contracting out their production ended up partnering with traditional breweries that brew cask ale. Each of these was described as mainly a partnership of utility that matched production needs with breweries that were able to meet it. One of the contract breweries said they were able to integrate the bread beers into their process easily enough after some experimentation (but was not able to participate in a full interview). The other full range bread brewery speculated that the brewers they contracted with actually became more open to learning as a result of their partnership. Since they started working together, that brewery had experimented with local partnerships highlighting herbs from a botanical garden in one batch, and also started examining some of their operational methods.

4.1.3 Mobilization Capacity

4.1.3.1 Institutional Arenas

The institutional arenas used to to develop these experiments were almost entirely informal conversations between collaboration partners. The ways in which Brewery 1 initiates brewing collaboration brewing projects is simply through contacting potential partners to see if they're interested in the project. They do have a loose set of three criteria for breweries they would like to partner with, which are a demonstrated organizational interest in charity, community or sustainability. When possible they try to work with breweries that are embedded within their local community, though interviewees expressed that as they started up this partnership model it was more important just to get participating partners. For each project, they also try to identify a local charity to receive the proceeds of the surplus bread beer and to raise awareness for the launch. The aim is to build community with partners as well, and actors from both organizations will attend the 'brew days' to help rip up the surplus bread and make it a fun process. In some cases these collaborations were built on existing relationships of the collaboration manager of Brewery 1, while some were recommended or reached out themselves.

There are two cases of more formal institutional arenas. For Brewery 2, who tested and developed a full range of bread beers to contract, their experimentation took place through more conventional business development. They hired a master brewer and a food science technology consultant to test the bread brewing process and develop core recipes. After the testing process, they worked to find a full time brewery that would contract to brew their bread beers. The interviewee from this brewery expressed that the process essentially took the form of internal research and development, and the contract brewer hired was more of a utility choice than a collaborative partnership. However, as the practice of brewing with bread is not widely accepted in conventional brewing industries, they had trouble finding a brewery willing to use the practice full time. This shows constraints of trying to find support for a niche practice, but in this case the initial research and testing from respected beer industry actors helped bring legitimacy to the brewery's pitch.

The other more formal experimentation arena was supported by the Circular Economy group of Zero Waste Scotland's business support services. Funded by the Scottish government and European Regional Development Funds (ERDF), the CE program was designed with a specific mission to support SMEs with no-cost consultancy services to identify sustainability opportunities and demonstrate tangible CE practices. This is done through an initial conversation with the organization about the CE concept and practices and what might apply to that specific business. The conversations with the food industry sector representative and two SME breweries led to exploring surplus bread brewing projects. They had each heard about the practice from media stories of Brewery 1's bread brewing projects and thought it would be a good circular project to try. ZWS facilitated introductions with local bakeries that would supply bread, and after some experimenting they each launched their single release bread beer. Each brewery decided to integrate the practice full time for at least one beer in their core range and have continued their relationship with ZWS to discuss potential further cleaner production projects or resources. These experiments served as a demonstration for ZWS to show other SMEs the benefits of experimenting with new forms value capture, and have positioned the craft breweries as visible frontrunners for circular economy and sustainability innovation.

4.1.3.2 Opportunity Structures

The perceived window for opportunity that sparked the experimentation processes with recovered bread brewing was realized by a food waste activist in the UK who saw the single-release 'Babylone' beer launched by the Brussels Beer Project, which claimed to be the first modern brewery to brew with recycled bread. This food waste champion saw the

opportunity to experiment with and scale this practice to recover the material values of unsold bread, raise awareness among consumers about food waste, and to encourage adoption of the practice in the brewing sector. This actor felt the business case could be viable as there is growing public interest in sustainable forms of consumption, especially in food systems, combined with a craft beer sector characterized by community engagement, collaborative and experimental brewing projects, and a consumer base interested in the stories behind new beer styles. This led to the establishment of Brewery 1 as a social enterprise brewery designed to impact beer and food systems by collaborating with breweries for single-release recovered bread brews, contracting their own full range of beers to be brewed with recovered bread, and conducting extensive communications campaigns to raise awareness of the project. A significant part of the perceived opportunity structure is the idea that craft beer is not just a way to demonstrate new food systems, but provides a fun communication tool that garners interest and engagement among groups that might not otherwise be actively aware of sustainability issues.

The perceived opportunities for breweries collaborating with Brewery 1 were much more varied. While most interviewees acknowledged the importance of addressing food waste, the motivations for action were often driven by the co-marketing benefits of the collaboration brew projects, an interest in trying unique brewing methods and ingredients, desire to raise funds for a local environmental charity, or simply as another brewery collaboration. In many cases these projects were designed so the release of the beer could happen at a community event, such as a festival or fundraiser, to build excitement and reach a larger audience than would be available at the breweries themselves.

Among interviewees, there are mixed perceptions of the broader opportunity being met by the practice of recovered bread brewing. Brewery 1 considers the practice a chance to practically contribute to food waste solutions through a scalable symbiotic exchange and to raise awareness through educational branding. However, other actors were doubtful, or at best skeptical, of the potential for this practice to scale within the beer industry for real environmental impact. These interviewees more often expressed that the novelty of the project was well suited to educate consumers about food waste issues, but would not be a suitable full time practice as it complicates the brewing process and, more importantly, changes the ability of brewers to design recipes for consistent and nuanced malt flavor profiles.

For the few actors integrating recovered bread brewing into their full time practices, the interviewees typically perceived a greater opportunity for action but also greater levels of commitment and capacity to pursue that action. For example, the founder of Brewery 2 relied on a background in beverage industry marketing and research to conduct feasibility studies and contract a brewery to make the beer, but also utilized an existing relationship with the local baker who could guarantee a consistent supply of bread. For the breweries working toward community ownership, these actors expressed the opportunity to connect local bakers and brewers as redevelopment tool for local industry and community.

These actors perceived utilization of unsold bread as a positive environmental aspect that was complementary to their broader sustainability interests of contributing to local economic and cultural development through local artisanal products or gathering places. In this case partnering with local bakers was a way to highlight the quality of bakery products rather than fighting food waste, backed by the perception that consumers are more likely to choose a beer that positively presents its ingredients, rather than perceiving the bread contribution as 'recovered waste.'

Lastly, the breweries who implemented the bread brewing after an initial pilot supported by ZWS perceived an opportunity to receive no-cost consulting support to explore initiatives they did not have capacity to research or test. Interviewees stated that the knowledge and connections that the business support services' food industry representative brought to the table made the partnership seem like a mutually beneficial chance to explore and demonstrate tangible examples of circular economy practices and value creation in a brewery.

4.1.3.3 Repertoires of Mobilization

The techniques being used to sustain momentum of this practice are mostly the development of sustainable business models that seek to utilize recovered bread as a method of value creation for the breweries and their communities. One of the breweries implementing this practice full time is a social enterprise brewery, the two planning to implement it are becoming community-owned breweries, and the others are more conventional SMEs. Brewery 1 has established relationships with an industrial scale sandwich manufacturer to receive the unused loaf end slices, with the hopes of scaling up their production and addressing such 'behind the scenes' food waste at industrial production levels. All other breweries implementing the practice are partnered with a single baker to develop local artisanal identities and take advantage of co-marketing or other resource sharing opportunities. One of the community-owned breweries is actually planning to move into a shared space with their bakery partner, who also bakes bread with their beer as an ingredient, to establish a symbiotic production site.

Those breweries are all rooted in a local community, whereas Brewery 1 is a contract brewer that is not quite embedded in any place or community. Brewery 1 is also the only actor who is deliberately trying to promote the project to be scaled up in the broader brewing industry, and is therefore employing different mobilization techniques. These consist of expanding their business model and continuing to develop collaborative brewing projects with actors at a broader geographic range and at larger scale breweries. They have recently established business locations or collaborative brewing partnerships in 6 countries outside of the UK. Interviewees suggested the countries just experiencing initial growth of craft beer sectors, such as Brazil and India, may be good countries to integrate the practice of brewing with recovered bread into the development of the industry. Within the UK, they are exploring partnerships with larger brewers to introduce the practice to the more well-known and established industry brands and their consumers.

Lastly, Brewery 1 is considering options to fill an identified need if this practice has a chance to scale up, which is as a third party supplier that can act as a collector and distributor of surplus bread to breweries. This helps breweries adopt the practice without any logistical effort beyond normal purchasing practices and could ensure a reliable supply of bread for those who might be interested in utilizing the practice full time.

4.1.3.4 Critical Change Agents

Critical change agents are present in different roles throughout the innovation network. The food waste activist that founded Brewery 1, and the organization itself, acted as champions of the practice with high motivation, charismatic media presence, and and an organizational ethos to address food waste through beer. This was absolutely essential to move the practice from one unique demonstration in Belgium to a growing network of users across the UK and beyond. Through the various activities of Brewery 1, which included public education campaigns, collaborative brewing projects, and their own range of beers, they also positioned themselves as frontrunners of the practice and intermediaries to facilitate collaborative experimentation among other industry stakeholders.

However, there was much support needed to grow this network. The openness of early brewery partners that engaged in testing the practice were key to proving that brewing with recovered bread could make good craft beer. Some of the partners engaged in early experiments in London also served as champions of the practice, making themselves available to give advice to brewers who were considering trying it. Each individual experimentation group also required key change agents for that project, often in the form of intermediaries who would help connect breweries and bakers.

Other key intermediary actors were ZWS, who provided a platform for its partner breweries to explore sustainability initiatives and facilitated the initial relationship between those breweries and their local bakeries. This intermediation was key in allowing those stakeholders to test bread brewing and develop full time working relationships for continued action.

4.2 Experimenting with Recycled Water Beer

4.2.1 Relational Resources

4.2.1.1 Range of Stakeholders

The range of stakeholders involved in developing and demonstrating the innovative practice of using recycled water for brewing has grown from one regional cluster of actors in Oregon in 2014 to include regional networks of water utilities, home brewers and craft breweries, and their communities in seven states (and even to Singapore in one instance). Over 40 craft breweries have now participated in recycled water demonstration experiments, along with about 100 homebrewers. However, though the final product being demonstrated is craft beer made with recycled water, the socio-technical niche being showcased is actually the state of water technology that can be used as any fresh water would, such as for drinking or making beer. Therefore the range of stakeholders involved includes a broad network of water utility actors, the engineering companies providing technology to treat the water, brewers who create demonstration brews from the water, the regulatory bodies which govern environmental quality and health standards, and the public - whose perception will influence the development of recycled water regulations and uses.

A high level of knowledge, technology, and regulatory authority is necessary to facilitate recycled water innovation niches because of the potential environmental and health concerns associated with using treated sewage water. Utilities must gain approval from regulatory agencies for experimentation with recycled water for human consumption, which often requires treatment well beyond drinking water standards for cautionary purposes and to foster public acceptance. The public is a key stakeholder because their reception of the beer brewed with recycled water is a major factor in future regulatory decisions.

The media was also identified by interviewees as a key stakeholder of sorts. The organizers of each demonstration project tried to use carefully crafted messaging for participants and the public to focus on the quality of the water being used instead of its history as sewage water. As most publicity about the projects was through media outlets, ensuring journalists had a proper understanding and messaging for their stories played a key role in shaping public opinion.

There are also a number of stakeholders not tied to any of the specific geographic locations where these projects took place. These consist of water industry or water sustainability organizations, including a trade association aimed at advancing recycled water acceptance and

use, a not-for-profit education and training association for water quality professionals, water conservation and reuse non-profits, and national craft brewers associations.

In some cases, actors are engaging universities and the academic research community to support the refinement and testing of recycled water technologies and outputs. Similarly, utilities producing recycled water are drawing on the support of medical professionals who can provide legitimacy to the safety of recycled water being beyond even the standards of recycled water.

Lastly, in some cases philanthropic organizations can be a key partner. Some of this experimentation was made possible with grant funds geared toward innovation for sustainable water management futures, as well as technology donations and sponsorship from established water technology companies.

4.2.1.2 Morphology of Social Network

As with the network of bread brewing experiments, this innovation network is characterized by multiple clusters of regional actors developing experiments in their area, connected by key actors across the clusters. These regional clusters are generally dense with local actors and strongly connected to other geographic clusters in a strong web-like morphology built on existing network connections of water professionals.

Each regional cluster is centered around a utility wastewater treatment and recovery facility that organizes a local recycled water demonstration experiment. They connect other regional actors including the brewers who will receive and use the recycled water, local water organizations (e.g. conservation and education nonprofits, watershed councils, etc.), local media and politicians, and sometimes universities or other partners. The local audiences engaged consist of attendees at community events, beer festivals, or water technology and sustainability conferences.

These utilities generally provide the connection beyond the regional cluster of actors to form the larger network. A hierarchical relationship is their connection and dialogue with their state Department of Environmental Quality that is responsible for permitting water uses. Utility actors also hold key relationships that link the champions of the various distributed regional projects taking place within this network. It is seemingly the connection and openness of key actors in early projects that allowed the practice to spread from its start in Oregon, to Milwaukee, to Florida, and back to Arizona in the Southwest (just its initial path). Despite geographic distance, the connectivity between champions of each project is what allowed reflective learning and continued development of such projects over time, leading to a more formalized network of recycled water beer champions known as the Pure Water Brewing Alliance (PWBA). This provides an organized forum to maintain national conversations among water stakeholders to facilitate aggregation and spreading of knowledge throughout the network. Although the scope of this study is the network that has formed in the US, in 2018 the network helped create a similar demonstration beer project in Singapore for the 10th anniversary of the Singapore International Water Week (SIWW). This shows early signs of this social network (and socio-technical practice) continuing to spread outward.

4.2.1.3 Integration of Various Networks

Grey literature review and personal interviews revealed substantial integration of actor networks. Key actors interviewed regarding their experimental projects in Oregon, Florida, and Arizona referenced existing industry relationships utilized to spread the idea and

information for recycled water projects. After organizing the first recycled water competition with a homebrewers association in Oregon, the utility Clean Water Services (CWS) sent samples of the top 4 awarded beers to the 2014 WEFTEC event in New Orleans, which is a conference for water reuse professionals. After seeing that demonstration, a reclaimed water director with the Hillsborough County Public Utilities utilized his role as chair of the 2016 WateReuse symposium in Tampa (the main city in Hillsborough County) to conduct a similar homebrewers competition with recycled water. WateReuse is a not-for-profit trade association supporting advocacy, education, training, research and funding for water reuse applications, utilizing symposiums co-sponsored by Water Environment Federation (WEF, the organization behind WEFTEC) to support the water reuse industry. Over 100 homebrewers participated in the Hillsborough County competition, and the top 20 were showcased at the symposium that year with over 600 people trying samples of the recycled water products.

After Pima County (Arizona) began planning their own competition, this time scaled to provide recycled water to 26 commercially operating craft breweries in Arizona, the levels of interest being shown from other utilities and water actors led to a clear need to organize support for this practice. As utility partners and WEF saw these partnerships develop and create a growing interest in recycled water demonstrations through brewing beer, they saw the opportunity to organize actor involvement by establishing the Pure Water Brewing Alliance (PWBA). Supported by WEF and involving many of the key actors who organized or participated in experimental brewing competitions and demonstrations, the PWBA describes itself as "a group of utilities, brewers, engineering firms, and technology companies involved in brewing beer with recycled water" (WEF 2019).

In addition to water professional networks, experimentation actors also utilized existing craft beer networks to engage craft beer SMEs. Interviewees from breweries, utilities, and NGOs discussed network overlap through participation in the annual Craft Brewers Conference (CBC) organized by the Brewers Association, a national not-for-profit trade association for breweries and homebrew associations in the United States. Several water sector interviewees have given presentations on water efficiency and reuse options at the CBC and remarked with surprise how many brewers were interested in water issues, how knowledgeable they are about water science and regulations, and accordingly their excitement for a chance to brew with recycled water. Interviewed brewers also pointed to the CBC as an area where they heard about recycled water competitions even before the development of their local projects and chances to participate. They also cite the Brewers Association as a prominent network providing resources for sustainability issues such as benchmarking tools and potential reduction measures for water and energy use.

Local brewers associations provide a similar networking function. One brewer interviewed in Arizona cited their local association, the Baja Brewers Association, as the way they found out about the AZ Pure Brew competition opportunity and how they connected to collaborate with other breweries on the project. The Arizona competition also utilized existing local networks supporting research and education on water sustainability and wastewater issues, such as a collaboration between Pima County Regional Wastewater Reclamation Department and the University of Arizona's Water and Energy Sustainable Technology Center (WEST Center) that drives research and technology development of water, wastewater, and alternative energy in the community. Notably, some of the brewers interviewed already had relationships from projects with the WEST Center and key actors from the County and were thus consulted in the design of the competition.

4.2.1.4 Power to Act

Though interviews indicate the relationships within this innovation network were mostly smooth and collaborative, there are some clear hierarchical power structures that inform how this socio-technical niche has developed. The main drivers of these projects are the regional wastewater utilities who have the financial, relational, and technical resources to facilitate experimentation with recycled water for human consumption. Physically, these utilities receive and treat the sewage water providing the raw resource for these projects. This position means they have established relationships with key technology companies involved in water treatment and can engage these companies to experiment with treating water to the high standard required for human consumption.

Regional utilities and governments are responsible for meeting citizens' water needs, treating their wastewater, and trying to ensure secure water supplies for the future. In areas projecting future water instability due to climate change, potential drought, or overconsumption, this includes advocating implementation of sustainable water management practices. As such, they are considered legitimate actors able to organize these competitions, provide recycled water to interested brewers, frame the story of the project, and send demonstration beers to symposiums for education. One interviewee described how, similar to other circular economy trends, their industry paradigm has shifted from finding the safest ways to dispose of treated wastewater to the best ways to reclaim value from their wastewater 'resource.' For example, Clean Water Services in Oregon now tries to retain the inherent value of resources in their wastewater through activities like removing nutrients to create and sell fertilizer and using a biodigester to generate energy from wastewater instead of just finding safe disposal methods of these components. As these activities simultaneously create new product values by removing biological and chemical components from wastewater, interviewees feel the water by-product being reclaimed has been heavily invested in and can be treated directly for human consumption instead of being discharged to surface water and later treated from scratch as a new drinking water source.

However, regional utility actions regarding use of treated wastewater is restricted by state regulations enforced by the state Department of Environmental Quality. This limited actor options initially, as the first idea by CWS was to provide recycled water to commercial breweries for a demonstration competition (as was later done in Arizona) but they found the regulatory barriers too complicating and decided to host the competition for amateur homebrewers instead. Yet all three utility interviewees highlighted their existing relationships and open dialogue with regulators as a key to any initial permitting and the eventual regulatory changes to allow increasingly permissive uses of the treated water. Interviewees also discussed an interesting dynamic between regulators and the public, expressing that while the scientific testing and evidence of water quality was helpful in obtaining regulatory permits, public perception was equally important in making regulators feel able to allow a practice that previously would not have been thinkable due to the "ick factor" of people not being comfortable with the history of the water as sewage water.

In these projects, the brewers themselves have considerably less power to act. They are essentially invited to participate (or in some cases, to apply to participate) in the utility organized competitions and can either choose to join or not depending on their perception of the opportunity. Once participating, brewers had to work within the confines of the competition organizers. They're generally told when they can receive the recycled water, given a specifications sheet of the water content when they receive it (and in some cases provided with supplemental minerals to create their ideal water profile), and given a date by which to submit their final brew product. The two projects using commercial breweries, in

Arizona and Idaho, each included meetings to inform participating brewers of the intent of the competition, to ask brewers to give their beers a name that positively reflects the high quality of the recycled water being used, and to provide information and language for the brewery staff to properly communicate the beer.

In the homebrew competitions the organizers branded all the beers under the same "Pure Water Brew" label to avoid the potential naming issues. Despite limited capacity for action, many brewers were excited for the chance to be given this pure water, which is essentially a 'blank slate' compared to the natural mineral contents of normal drinking water supplies. Interviewees expressed having fun getting to envision and create a beer, starting with the pure water, that could highlight the unique ingredient and give them a chance to experiment. For example, one interviewee mentioned how typical water sources in Arizona have too high a mineral content to brew a pilsner style beer, so they chose this style for their highly treated water and because this 'clean' style of beer would align with the intended messaging.

However, while brewers are accepting of the practice and make good spokespeople for it, they are reliant on the investment in treated water supply from local utilities. Interviewees say the process is still very expensive and will likely not be available any time soon. There are limited examples of breweries that have been able to finance their own wastewater treatment facilities on site, including three in California and one in Arizona. These have unique financing situations and understanding of the need to prepare for potential changes to wastewater regulations.

The expense of treating water to exceed drinking water quality is a barrier for utilities as well. For example, the AZ Pure Brew Competition was catalyzed by a $250,000 grant from the Arizona Community Foundation, and the project in Florida will utilize an education grant from the WateReuse foundation to continue with their brewing demonstrations. Even with funding, all utilities utilized partnerships with private sector companies to experiment with treatment technologies for these projects. Interviewees from the public sector acknowledge the crucial contributions of private firms to implement these projects.

4.2.2 Knowledge Resources

4.2.2.1 Range of Knowledge

The range of knowledge involved in this innovation network is primarily related to water and wastewater systems. Much of the knowledge required among actors is explicit technical knowledge of wastewater treatment and recovery systems and scientific understanding of water chemistry and microbiology. Deep institutional knowledge of water planning and regulatory systems helped actors understand how to embed these innovative experiments in the sociotechnical landscapes in which each regional project was conducted. To support actors in using recycled water for human consumption, actors also required key research partners who understood human and environmental health issues related to water content for ensuring that the water was safe and helping communicate this message to users (brewers and consumers).

Many actors brought significant conceptual knowledge as well, related to governance shifts in water management (such as the recent shift from integrated water resource management to the One Water approach) and best practices for communicating water issues. This was explicit in interview responses from the organizers of the first recycled water brewing competition in Oregon, who deliberately crafted the project's educational plan based on recent academic literature about water messaging for the One Water concept. Their plan

emphasizes all water has been 'recycled' over its 4.5 billion year history on Earth and should be judged on its current quality rather than its history. The interviewee described the importance of messaging in relation to the "Overton Window" concept, which describes the window of opportunity for policy feasibility as public perception is influenced to accept an idea that was previously considered radical and unthinkable (such as using reclaimed sewage water). Actors throughout the network described deliberately framing the water with terms that emphasized the advanced treatment techniques and clean quality of the water rather than its reclamation from sewage.

4.2.2.2 Frames of Reference

The dominant story shared by many actors interviewed was that conditions such as water insecurity, overconsumption, and increasing drought conditions require drastic shifts in water use for a sustainable future. This was often shaped by the location of the interviewee, as some projects took place in arid areas, some in regions facing water overdraw and saltwater intrusion, and others in areas seemingly stable for now but projecting future water insecurity with climate projections and increasing populations.

Many interviewees describe the need to use water that is 'fit for purpose,' meaning that fresh water should be used only where necessary, while other uses such as flushing toilets, cleaning, and irrigation should use 'greywater.' A few interviewees explicitly connected the idea to concepts of circular economy, in that valuables resources such as water should be utilized as long as possible before being disposed of (in this case sent down the drain to wastewater treatment or recovery plants). These interviewees expressed that recycled water for direct potable reuse (DPR) is by no means a magic bullet solution in itself, but that it may be a valuable tool within future water management systems and therefore should be explored and developed for where it is needed.

For the participating technology companies that donated equipment and sponsored some of the projects, wastewater utility interviewees expressed that those companies likely have multiple interests in being involved. This includes marketing and corporate responsibility, a chance to test and apply their equipment in a real-world setting, and maintaining good relationships with utilities as a strategic business move given a potential growth in the adoption (and purchase) of water recycling technologies.

Interviewees also described how many brewers are increasingly aware of water issues. Many of them are operating in regions with drought or water scarcity and are actively trying to improve their water to beer production ratios. Further, multiple brewer interviewees in the Arizona project also participate local water conservation schemes and efficiency initiatives.

While some of those brewers described water efficiency and conservation as a social responsibility of businesses in those regions, they also mentioned economic drivers related to water. While water itself is fairly cheap, brewers in some regions are charged more than other industries for their wastewater discharge because of the high levels of biological and chemical oxygen demand, total suspended solids and other composition characteristics that place higher strain on wastewater treatment plants. Therefore, some craft breweries are beginning to install wastewater treatment systems on-site, or at least are interested in developing relationships with their water utilities to prepare for expected regulatory pressures.

4.2.2.3 Integration of Different Spheres

Most actors felt that the range of stakeholders involved in their projects were on the same page and had mostly shared frames of reference shaping their perspectives, though to varying

extents. Though perspectives integrated fairly well during project implementation, utility and NGO actors clearly approached the project from a perspective of trying to influence public perception of water systems and technologies, while breweries were often just happy to participate in a brewing competition and the chance to create water profiles from a blank slate. However, some breweries interviewed spoke explicitly about their organizational goals of trying to create a sense of place and environmental stewardship through their brewery communications and activities.

This was clearest with the breweries interviewed in Arizona, a dry desert state. The breweries interviewed showed high awareness of water issues in terms of scarcity, their impact on wastewater treatment systems, and the need to improve water use efficiency in operations. While some expressed limited ability to act on that knowledge, some of the interviews highlighted pre-existing relationshps between breweries and wastewater utilities, local business support services supporting water efficiency and conservation, and regional watershed and water conservation NGOs. In one case, a brewery had even participated in projects with their utility (Pima County Wastewater Treatment Departnent) and their collaborative research with the University of Arizona's Water and Energy Sustainable Technologies (WEST) Center. However, it is likely that these findings represent the frontrunners among participating breweries rather than the norm. While interviews were conducted with a sampling of 4 out of the 27 participating breweries (each of which was initially contacted) it is possible that those interested in participating in research interviews regarding the project are also more engaged with external stakeholders and environmental issues than some of those who simply participated in a brewing competition for its own sake.

The breweries interviewed in Idaho also expressed awareness of water scarcity, but often pointed to drought issues in California and Southwestern states as a driver of their awareness. This may suggest that their perspectives are not fully aligned with the City of Boise, who organized the project, and their understanding that the high desert city is also grappling with sustainable water management trajectories. This supports the statements of a water utility interviewee who felt that places that don't have extreme droughts may feel overly comfortable with their water security (or just don't think about it) despite the many water resources coming from groundwater sources that are at risk of becoming overdrawn.

Apart from external water issues, there seemed to be shared understanding about the relationship between water systems and beer production. The actors from the water sector spoke anecdotally about attending or speaking at water presentations at the annual Craft Brewers Conference and realizing the deep interest of brewers in reducing the water ratios of their beer production and staying abreast of water regulations and issues. They also described being surprised at the technical water knowledge of brewers, with one interviewee remarking that "some brewers can go 'toe to toe' with wastewater professionals on water quality and chemistry."

This all manifested in the shared perception among actors that beer, and the brewers who create it, could provide a positive educational tool for communities. In Hillsborough County, when they had attended events with samples of recycled water for people to try there was limited engagement and considerable hesitation about drinking this former sewage water. However, when they served beer made with the same water, the level of interest skyrocketed - with over 600 people trying samples of the top homebrewer entries. Interviewees describe that when the product is one step removed from the recycled water itself, and provides the sensory experience and story that people often associate with craft beer, that interest seems to overshadow any skepticism about the recycled water among consumers.

4.2.2.4 Openness and Learning

To embrace and experiment with a niche innovation that is radically different from the sociotechnical norm required considerable capacity for openness and learning among most actors involved. This is especially true for the use of recycled water from sewage, where interviewees and literature describe the 'ick factor' (the initial perception that it is gross to drink former sewage water in any form) as a significant barrier to acceptance.

However, among water professionals the capacity to absorb new ideas seems to relate more to the utilization of beer as an innovative engagement technique rather than openness to using recycled water. Most of these actors are informed by experience in the water sector that has provided a different perspective of water than most of the public. The utility actors are from organizations with institutional history of innovating for water reuse and wastewater recovery, such as providing treated water for irrigation purposes and groundwater discharge or utilizing wastewater for biogas energy generation and fertilizer. This has provided an understanding of water technologies and quality that makes recycled water for human consumption seem more of a logical next step in treatment than a radical idea.

The capacity for learning shown here by water professionals is more of the ability to embrace new conceptions of sustainable water management which requires innovative education and engagement to make the public aware of water issues, technologies and behaviors. Interviews revealed the water professionals driving this were applying new best practices in industry communication techniques, as evidenced by direct application of the One Water and other academic water management guidelines. Personal learning and experience is also a factor. One interviewee with decades in the water industry expressed that the way the industry historically communicates with the public has been counterproductive, citing terms like 'greywater' and 'blackwater' (which are applied to water that has been used for washing or rinsing but is more suitable for irrigation or cleaning than freshwater) that give a sense of dirtiness rather than usability and thus limiting uptake. From the beginning, the focus of actors behind these niche projects have been to ensure that all stakeholders, including brewers and the media, use terminology that highlights the current quality of the water rather than its history. This was repeatedly mentioned as a critical factor for obtaining public receptiveness and eventual regulatory changes.

Therefore, the success of these experiments was contingent on openness of other involved actors to learn from the water professionals to understand and communicate the steps of water treatment and the proper terminology to use. Interviewees expressed that the involved brewers' experience with water made them very open to the technology and using the final product, and the brewing industry's focus on water combined with their role as community institutions that engage consumers through the stories behind their beer made them great spokespeople for the project.

This was evident in brewers' excitement at the chance to work with water that is essentially free of all mineral content, giving them a 'blank canvas' from which to add minerals and create water profiles necessary for types of beer they could not otherwise produce with their local water supply. Interviewees who presented the opportunity at the Craft Brewers Conference expressed pleasant surprise at how readily brewers accepted recycled water once they were given the specification sheets showing 'nondetect' (undetectable levels) across the main components of water quality testing. Similarly, the members of the homebrewers association participating in the annual Oregon competitions, who are experienced amateur homebrewers, utilized the opportunity to consult with local experts and receive donated mineral additions for their beers.

Though this can be seen as excitement to use blank water in the brewing process more than an interest in water sustainability, for the utility actors this excitement and openness was exactly what they were hoping for - that a community of water users who are deeply concerned with their water inputs were more interested in the high quality of the water they were receiving than its history as sewage water.

There were a very few actors who did not follow these messaging techniques. For example, one wastewater utility in Wisconsin branded their recycled water beer 'Activated Sludge.' Activated sludge is a process of aerobic sewage treatment, making this name a funny and fitting name for water professionals but counterproductive to the goals of this project, according to one interviewee. Similarly, despite meetings with project organizers in Idaho to get breweries on the same page with positive messaging, one of the brewery spokespersons could not resist the urge of a sewage joke when speaking with the media. This was a concern throughout - many actors explained that though they could do everything possible for participating actors to properly communicate the purity of the water, the media's interest in a catchy headline would lead to sensationalized messaging that amplifies the 'ick factor,' such as 'toilet to tap,' 'sewage to brewage,' and other misrepresentations. However, one of the organizations commissioned a media analysis report to evaluate the success of their communication campaign and found that overall the media was receptive to the goals behind the projects and therefore absorbed and applied the messaging used by project actors.

Interviewees also expressed the customer base of craft breweries as a very open and receptive audience to test this product on. Craft beer communities are generally interested in trying new types of beer, including experimental varieties that would be unlikely to be brewed by a major brewer. Findings suggest this openness to new beer types, and a general interest in the stories or partnerships behind a specific beer release, provided an eager audience that was more focused on the beer product than the water used to brew it. One interviewee described the project as engaging people through beer and 'sneaking in' the recycled water messaging to normalize the practice by emphasizing the benefits of the final product.

4.2.3 Mobilization Capacity

4.2.3.1 Institutional Arenas

The institutional arenas used by actors to develop recycled water brewing competitions were largely through the decision-making processes of regional wastewater utility organizations.

The initial idea was hatched in an advisory commission meeting of the regional water utility Clean Water Services (CWS) in Oregon, which includes 15 representatives from local neighborhoods, businesses, environmental organization, and agricultural groups. The commission is designed to review major policy issues and make recommendations to the CWS Board of Directors. When discussing how to initiate community conversations about the potential use of recycled water for human consumption in sustainable water management plans, a commission member considered 'the grandfather of craft brewing' in Oregon suggested that the best way to talk about water was to make beer. The Board liked the idea and CWS began exploring how to organize such a demonstration project.

The initial institutional arena was informed by the Oregon Department of Environmental Quality (ODEQ), who is responsible for regulating and permitting water and wastewater issues. In the first year, utility organizers were not able to receive permitting to provide pure recycled water for brewing or provide recycled water to commercial breweries. Therefore the first competition in 2014 was actually taken from a river near where effluent was released

(where the water was calculated to be 30% effluent content) and given to 15 amateur homebrewers.

Based on this initial experimental project, the following year they received a permit allowing use of recycled "high purity water to produce alcoholic beverage for educational purposes." The final beer product could be given away for education but not sold. The process of gaining regulatory acceptance was driven by growing public acceptance. Interviewees considered the regulators unlikely to permit recycled effluent based on the technical specifications alone, with the idea that the public would not be ready for such a practice. The unique nature of the story drew much media attention and the carefully crafted messaging campaign seemed to effectively convey the reasons for the project, the high quality of the water treatment, and the fun chance to experiment with beer made from effluent. By the time of a public hearing to receive comment on the allowance of experimentation with recycled water for human consumption, there had been hundreds of media stories globally highlighting the project and the hearing demonstrated a general consensus of support for the practice from water industry professionals, environmental groups, and general members of the public.

From this first experiment the practice spread along the network of water utility professionals also involved in the WateReuse association. The wastewater reuse directors in Florida were slated to chair the 2016 symposium in Tampa, Florida and decided to develop a similar recycled water homebrewing competition to showcase the winners at that event.

The largest recycled water brewing competition, and first one to use commercial brewers, was developed in Arizona in 2017 with the support of a grant from the Arizona Community Foundation focused on scalable water innovations. The grant focus on community partnerships expanded the institutional arena and provided funding for higher levels of engagement. The lead organization, Pima County Wastewater Treatment Department, partnered with public, private and nonprofit partners to create an action team that would work with the Arizona Department of Environmental Quality (ADEQ) and commercial breweries to demonstrate the first permitted uses of recycled water in craft beer SMEs for commercial use. This has opened the door for easier replication, evidenced by the City of Boise contracting to use Pima County's mobile water reclamation facility for a small recycled water brewing demonstration and the Idaho Department of Environmental Quality (IDEQ) adopting new recycled water legislation based on Arizona's template. Other states are now considering similar legislation or permitting based on these demonstrated successes.

4.2.3.2 Opportunity Structures

The opportunity structures identified by the champions of this practice seem to have grown in ambition with each successive recycled water brewing competition.

From the conversation in Oregon discussing how beer would be a great tool to experiment with and communicate the state of water recycling technologies, the first project was launched with limited funding and scope (as discussed, partially limited by regulatory barriers). The utility group worked with equipment manufacturers to develop a small scale, 1 gallon per minute recycled water system that would produce low quantities of advanced treated water. The first competition had water for 15 homebrewers containing just 30% treated effluent from the river water directly adjacent to the effluent discharge area. The success of this pilot project allowed actors to perceive opportunity windows for more ambitious projects, as shown by the growth of the annual Oregon Pure Brew competition and spread of the practice elsewhere.

However, the CWS actors already understood the opportunity of resource recovery through existing business practices. Interviewees described how wastewater treatment plants were increasingly becoming "wastewater resource recovery plants" with opportunities to create value out of the wastes that had previously been disposed of at high cost. As their operations were already removing nutrients from water to sell as fertilizers and capturing gas for energy generation, these activities contributed to a highly (and expensively) treated water resource that was then being discharged into local rivers - to be treated again in the next downstream drinking water facility using surface water from that river. To maintain the investment in that water, they realized they could use this already treated water directly instead of sending into the river to be treated again. The recycled water beer became a product to test this possibility and make the product palatable to consumers. While the cost of production is nowhere near competitive compared to normal beer due to the expense of water treatment, as the technologies are developed further and costs are already undertaken to create other products through resource recovery, then actors felt this was pioneering a system that would lay foundation for a potential economic activity.

Many of these demonstration projects were shaped by specific event opportunities to showcase the recycled water beer. Initial homebrew competitions were organized for the winners to be shown and shared at conferences for water reuse professionals. Other competitions provided samples and educational material at community events and festivals, which provided an already engaged public audience. In some cases, these were brewed specifically for community water awareness events.

For participating breweries, the window of opportunity was simply the invitation from project organizers to brew with recycled water for demonstration or competition projects. However, there were various perceptions on what this chance meant. For some interviewees this was a chance to act on their environmental values and convey a message to their customers and community. A few breweries indicated the opportunity was an important chance to develop relationships with local utility and municipal partners with recognition that a working relationship would likely be mutually beneficial as craft beer SMEs are subjected to wastewater regulations or for other potential sustainability partnerships.

4.2.3.3 Repertoires of Mobilization

As these projects have spread and grown, the key actors involved have utilized various techniques to sustain the momentum of this innovation network. From the first competition, water utility actors in different contexts were able to learn from each others' experience developing recycled water treatment systems, engaging with brewing communities and developing competition platforms, and implementing strategic messaging campaigns. This informal learning network allowed the innovation experiment to be translated and applied in different places and scaled up over time.

This social network has been formalized in the form of the Pure Water Brewing Alliance, which holds monthly calls as a platform to support new actors who are interested in bringing this type of project to their communities. As interest has grown, the members of this network are also creating an educational guide to help actors anywhere understand what is needed to implement their own experiments.

Some of the competitions were designed explicitly with scalability in mind. Arizona's project team was able to utilize equipment donation and sponsorship to assemble a mobile water purification truck that could enhance highly treated wastewater to potable standards. The idea was that this could be contracted and shared so that other communities could develop

their own educational brewing projects without having to purchase their own experimental system. For example, the City of Boise in Idaho was able to contract use of Pima County's purification facility for their own recycled water brewing demonstration to engage citizens and convince legislature to adopt the direct potable reuse regulations piloted in Arizona.

4.2.3.4 Critical Change Agents

This network was supported throughout by key critical change agents. CWS, who started the first pilot using recycled water for brewing, was already a frontrunner in wastewater recovery and reuse projects for CE. This was key for the organizational support to drive this project. Even the initial presence of diverse stakeholders in the group's advisory council, including Art Larrance, who is considered the 'grandfather of craft beer' in Oregon for his role in developing the craft beer scene in the 1980s, provided the creativity for this cross-sectoral CE demonstration. The actor at CWS who drove the project also acted as a champion for the initiative, bringing motivation and experience to overcome initial regulatory barriers and figure out how to start real-world experimentation that could be scaled up.

From there, existing water professional networks served as intermediary platforms to facilitate knowledge sharing among utility actors to inform further recycled water competitions around the country. Interviewees pointed to the presence of champions in each of these initiatives who were able to garner institutional support for these projects.

This was exemplified in the Arizona project, where the head actor from Pima County and their partners were able to build on existing relationships and develop new relationships to get the first permitted commercial uses of recycled water for human consumption, which brought the competition to craft beer SMEs instead of just homebrewers, and to expand resources and action capacity through solicitation of private sector sponsorship and equipment donations to build a mobile purification facility truck.

Lastly, actors from the Water Environment Federation (WEF) used their position as a nonprofit water professional association to formally host the Pure Water Brewing Alliance, which acts as a platform for frontrunners, champions and other interested participants to learn how to conduct recycled water brewing demonstrations and influence state regulations.

5 Analysis and Discussion

This section presents analysis and discussion of the findings from stakeholder interviews and literature review. The research findings are first analysed in terms of the IC building framework to consider overall IC developed in each network. After this the characteristics of each experiment network are analysed, along with the potential transformative capability of the innovation network.

5.1 Analysis: Surplus Bread Brewing Network

5.1.1 Relational Resources

The relational resources of the surplus bread brewing network consist of many actors, but with weak network strength or integration of networks. The somewhat tentative nature of many of the partnerships also showed limited initial trust between the craft beer SMEs and the Brewery 1 intermediary.

One interviewee expressed that Brewery 1 is not truly considered part of the craft beer community, as they contract out their actual brewing processes and therefore function more as a public relations brand than another brewery. This is not an uncommon perception of contract brewers (Garavaglia et al., 2018). This was generally not an issue for developing the partnerships, but it may have limited the levels of knowledge sharing and perceived windows of opportunity for further collaborative action (Abreu and Ceglia 2018, Wang et al., 2017). Interviewees who had worked repeatedly with Brewery 1 expressed a higher level of trust, supporting findings that repeated interactions presuppose trust and collective action, rather than the other way around (Spekkink 2015). Notably, the decision-making in that brewery was entirely in the hands of the head brewer, who helped Brewery 1 test the bread brewing process in its early phases and shares that experience with other potential partners. As a trusted brewer within the craft brewing community, this 'champion' role within the innovation network was key to gaining support and legitimacy for the practice as it spread (Klerkx and Aarts 2013).

When one actor described Brewery 1 as a PR brand rather than a brewery, this was not necessarily a negative perception but a description of that brewery's 'power to act.' As a social enterprise organization promoting a niche process, the ability to provide effective co-branding and positive media around the product (Rettie et al., 2012) was often a key reason others wanted to engage in the partnership. Introducing media connections to this innovation network drove public awareness and support of the practice, and therefore increased the opportunity window for breweries to participate in the collaboration (Drummond et al., 2018).

There was also limited diversity of actor types, especially across socio-technical scales. The network consisted almost entirely of craft beer SMEs, one of which was a social enterprise brewery and two of which were issuing shares to become 'community-owned' breweries.

The projects facilitated by ZWS were the only signs of government involvement and support, and their projects resulted in lasting working relationships with their craft beer partners and more immediate capacity for action (Rizos et al., 2016). Other signs of regime involvement are the use of this experimental practice by two large retailers - a grocery store that supplied bread for a collaboration brew they would later sell, and a large retailer who released a limited time bread beer among their own brand range. Neither of these engaged directly in the broader network, instead implementing the practice on their own but showing

the potential impact of the network's niche support to demonstrate potential scaling (Kivimaa and Kern 2016).

5.1.2 Knowledge Resources

The bread network relied on a smaller range of knowledge for the initial practice, particularly for any new knowledge. Yet, while the practical knowledge threshold was fairly low, there was a need to experiment with operational processes how to best brew with bread, from logistics of storing and transporting bread to integrating bread into the mash. As these SMEs are generally very lean operations, many would not be able to experiment with multiple iterations of the practice if it slowed down their production or was not guaranteed to result in sellable beer. This fits with identified barriers of eco-innovation adoption in SMEs (Rizos et al., 2016, Pigosso et al., 2018). However, as craft beer SMEs often brew single experimental collaborations, Brewery 1 was able to utilize multiple experiment partnerships as a form of open innovation (OI) to use the collective experimentation capacity of craft brewers to refine a recipe. From that point, they were able to legitimize the practice by having brewers who had done the experience speak to brewers who were skeptical to try it (Yoon et al., 2016, Xie et al., 2018).

Knowledge development appeared most effective in the ZWS experiment that deliberately prioritized learning for implementation of the practice (as opposed to a single project). Through regional and national development funds, ZWS helped these two craft beer SMEs experiment with bread brewing as a more deliberate market research project, and after successful launches decided to add one or two bread beers to their full-time product range. This shows that clear goal setting and understanding of actors' desired learning outcomes are important to harnessing value creation experiments for lasting effect (Frantzeskaki and Rok 2018, Bocken et al., 2018).

5.1.3 Mobilization Capacity

The mobilization capacity of this network has increased for some key organizations supporting recovered bread brewing, though it is imbalanced across the network. Mobilization capacity for brewing with surplus bread, or further sustainability partnerships within the network, seems to have increased in just three of the regional experiment networks. These breweries were the main source of change agents for the experimentation network as well, though the willingness of partner brewers to engage in the proposed collaborations was vital to any tangible action. The breweries doing full time bread beers have emerged as frontrunners of the practice who can potentially demonstrate market success of surplus bread beers and share their experience with others.

It is notable that Brewery 1, which was started by a food waste activist who connected with a beer professional to launch the social enterprise organization, followed sustainable business model experimentation principles fairly closely. Aligning with the literature, this included an initial value proposition to create a consumable product utilizing potential food waste, and experimental trials using open innovation partnerships to test their recipe and public reception before launching the full business (Bocken et al., 2018, Yoon et al., 2016).

Of the breweries continuing to brew bread beers in the core range, just one of those began doing so as a participant of a collaborative experiment (e.g. not the initiating brewey). One of the breweries supported by ZWS and CE Glasgow had been using their business support services to identify possible opportunities to integrate circular and sustainable practices in their business model. The initial experiment and soft launch acted as a product

experimentation that was deemed successful enough to integrate into the full range and to begin experimenting with another bread beer.

The ZWS project also shows the importance of developing new opportunity structures within the experimentation network (Smith and Raven 2012, Edmondson et al., 2018, Boons and Spekkink 2012) As an organization with explicit funding to support circular economy and waste reduction initiatives in SMEs, they were also able to expect higher levels of commitment and engagement from their partner 'clients.' This resulted in the full integration of the experimented bread beer into that brewery's full-time beer range, as well as ongoing partnerships exploring other CP practices such as CO2 capture.

It also raises interesting questions about the range of stakeholders in experimentation at different stages - though this government supported experimentation project was the one that was supported and successful enough to result in actual adoption of the practice, it was the media attention from Brewery 1's partnerships that made those actors aware of the practice in the first place. This suggests that grassroots experiments are effective venues for initially experimenting with and demonstrating radical ideas and can build initial perceptions of legitimacy for a practice that allows regime actors to then test it as well (Seyfang and Haxeltine 2012).

However, most of the breweries who participated do not perceive a window of opportunity to continue engaging in the practice. Though the network contained many regional clusters of bread brewing partnerships, very few of these were conducted in a transition arena that would help actors conceptualize their projects as a deliberate sustainability experiment or a stepping stone toward transition. This may suggest the loose network ties limited overall IC building for any transformative effect at this stage. One cause may be that because of the limited engagement of a one-time partnership, actors were not forced to develop a shared vision or final goal of the experimentation process as addressing a long-term sustainability challenge in the brewing sector, suggesting a missed learning opportunity (Bos et al., 2013).

5.2 Analysis: Recycled Water Brewing Network

5.2.1 Relational Resources

The rapid emergence of this innovation network and ability to influence public perception and regulation in such a short time shows the benefits of involving a wide range of stakeholders across sociotechnical system scales and boundaries (Kivimaa and Kern 2016). Increasing the network of support within various levels of the regime allows a shared vision and incorporation of the niche practice into the established regime actors (Abreu and Ceglia 2018). However, this was predicated on a somewhat pre-existing shared vision that water systems are shifting from treatment for safe disposal or discharge to water recovery. It seems that for these actors, what seemed a radical idea initially to the public is actually the logical next step in wastewater recovery systems. This allowed the involvement of major incumbent water equipment manufacturers, who donated equipment or sponsored events, as they are positioning themselves to be providers of preferred technologies as water recycling progresses technologically, regulatorily, and otherwise (van Mossel et al., 2018).

The rapid emergence of this network was also based on integration of existing networks and pre-existing relationships among established actors with high levels of trust (Spekkink 2013). For both water professionals and craft beer SMEs, existing network arenas were used to share ideas and knowledge and to demonstrate the final products. Water professionals took advantage of Brewers' Association conferences to give presentations on water issues related

to breweries, providing an audience of brewers with demonstrated openness to learning and improvement of sustainability practices. This again highlights the importance of various transition arenas to engage actors in understanding the need for and providing tangible demonstrations of sustainable practices (Tukker and Buter 2007).

Another significant factor in this network was the power to act (Köhler et al., 2019). Champions of this practice were mainly located in municipal wastewater utilities that had organizational experience implementing water reuse programs. This provided an organizational culture, and an established regime position, conducive to making the case for recycled water experimentation (Patterson et al., 2017). Relationships with equipment manufacturers also allowed actors to overcome cost barriers, especially in the Arizona competition where the project champion leveraged donations and sponsorships to create a mobile water purification facility. However, this also demonstrated power imbalances in the network. Craft beer SMEs could merely participate within the confines of the competition with limited chance of continuing the practice, as they would have limited capacity to fund water recycling experiments or connect with regulators. Some participants still found participation helpful as a chance to showcase their commitment to regional water sustainability and develop working relationships with their local utilities. Interviewees also expressed conceptual learning as they were taught how to explain the recycled water in the beer, and why water recycling is important. Yet this transition arena could be improved with more deliberate learning goals and resources for adopting sustainable practices.

5.2.2 Knowledge Resources Developed

The innovation network experimenting with recycled water for human consumption through beer brewing developed considerable knowledge resources over successive experiments throughout the network. The practice followed somewhat typical patterns of socio-technical niche development and growth (Geels 2018). The 'user group,' mostly consisting of water reuse professionals and (home or commercial) brewers in their community, deliberately developed small-scale recycled water treatment systems (to consumption standards) to test its capacity on wastewater (Mossberg et al., 2018, Palgan et al., 2016). But the group also clearly learned from and further developed their experimentation arenas as well, showing effective learning, translation and scaling practices (Astbury and Bulkeley 2018, Smith and Raven 2012). The first recycled water brewing competition organizer, who faced considerable institutional hurdles in developing the first competition, shared knowledge with other water professionals to organize their own competitions. This included technical practices regarding recycled water, but also organizational design concepts such as messaging to participants and media that would normalize the concept (Tukker et al., 2008, Vergragt et al., 2016, Gollnhofer 2017).

The technical improvements and knowledge sharing were supported by a wide range of water professional stakeholders, including utilities, private equipment companies, and academic research centers. The involvement of academic partners helped develop state of the art systems and brought institutional legitimacy to the project in the eyes of regulators and the public, supporting literature positioning universities as key facilitators of knowledge transfer for transitions (Geels and Verhees 2011, Giuri et al., 2019, Brink et. al 2018). From the brewery perspective, the existing knowledge of water quality allowed them to be an informed and eager first group to use recycled water.

This network also demonstrated more deliberate integration of knowledge ranges and frames of reference. While brewers already understood water quality, connecting with utilities helped grow understanding of the need to collectively understand and plan for sustainable water

management trajectories. Importantly, this was a two-way flow that allowed brewers to understand the need for utilities to plan water conservation and recovery strategies for sustainability, while utilities became more aware of challenges faced by craft beer SMEs in dealing with their wastewater outputs (Frantzeskaki and Rok 2018). In some regions breweries are charged more due to the high oxygen demanding contents of their wastewater, yet have limited capacity to implement on-site wastewater treatment compared to better resourced breweries. This integration of perspectives seemed to create mutual working relationships among key actors influencing their regional water systems, supporting experimentation literature showing transition arenas can create shared problem definitions and collective action (Healey et al., 2003, Boons and Spekkink 2012).

The whole process also showed high capacity for openness and learning among all actors. Significantly, though the projects were initially aimed at water industry professionals to demonstrate the high levels of water treatment available, the groups who showed the most learning may have been the public and the regulatory agencies. This shows that the range of knowledge of deliberate water messaging, which was also shared with breweries and their staff to become spokespeople for the process, was an important factor in generating learning and openness for broader scalability (van Meirlo and Beers 2018).

5.2.3 Mobilization Capacity

The mobilization capacity of the network has been driven by key critical change agents taking advantage of windows of opportunity at different stages (Wittmayer et al., 2017). The emergence of this experimentation network was characterized by clear knowledge sharing among frontrunners and coordination of multiple champions within the innovation network, supporting the added potential of complementary champions working in unison identified by (Klerkx and Aarts 2013). A significant step is the formalization of this actor network into the Pure Water Brewing Alliance, which can act as an intermediary platform to further facilitate knowledge sharing, relationship building and action among an increasing range of interested actors (Kivimaa et al., 2019). The development of formal networks and involvement of multi-sectoral actors at various niche and regime levels shows this niche practice is increasingly supported and being established within the water regime (Smith and Raven 2012). This is further evidenced by the network's ability to influence the external regulatory landscape, which shows increasing technological legitimacy and ability to scale (Markard et al., 2016, Boon et al., 2014, Dolata 2009, Geels and Deuten 2006).

The institutional arenas used in Arizona's recycled water brewing competition also support the benefits of institutional support experimental governance. The Arizona Community Foundation grant that was received by Pima County and partners was designed for innovative water projects that were both collaborative and scalable for a sustainable water system. This shows the true transformative potential of experimental governance if it is well supported in a transition management approach, as the initiative was able to leverage collective resources for an expanded project scope and impact. Since the Arizona recycled water brewing competition, they have taken their mobile purification truck to other states to partner with governments on their own demonstrations for social learning in their states.

The range of actors involved grew extensively across the industry and across socio-technical scales. The network spread within water utility networks to diverse geographic regions. The user network also stretched to include actors from civil society, private sector, NGOs and multiple levels of government. This widespread support shows promising potential for the experimentation network to continue developing this niche innovation, as evidenced by emerging legislation in several states with water issues.

5.3 Discussion

5.3.1 Institutional Capacity Building

This study found that each sustainability innovation network did build IC that can help to protect, further develop, and potentially scale the practices being tested. However, the distinct dynamics of each experimentation network resulted in different levels of overall IC.

In both cases, craft beer SME engagement was characterized by partnerships around a single (or limited) collaboration, which limited interaction time and therefore did not build strong relational resources with brewers (except in a few cases of repeated bread brewing collaborations, or in contracted bread brews). The findings also suggested a low quality of organizational learning, as many interviewees expressed learning something from the experiment, but few engaged in reflective learning or action based on the projects (van Poeck et al., 2018, van Mierlo and Beers 2018, Gonzalez and de Melo 2018). In innovation networks, repeated interaction in a transition arena is what leads to meaningful social learning among actors and development of a shared vision (Healey et al., 2003, Dlouhá et al., 2013).

A major difference between networks was the range of stakeholders actively engaged in designing and supporting the experiments. In the bread brewing experimentation network, there were relatively few actors continuously engaged in the practice and there is limited interaction even among those main actors. For example, though Brewery 1 was able to engage in collaborations with over 20 breweries, these forms of open innovation were sufficient to demonstrate the practice among brewers and possibly normalize the product for consumers (Davies et al., 2017, Yoon et al., 2016) but resulted in few relationships that would aid their efforts to further protect the niche or scale the practice (van Popering-Verkerk and van Burren 2017). However, the media attention and brand name developed through these relationships did allow that Brewery to create new windows of opportunity as a frontrunner and champion of the process (Wittmayer et al., 2017, de Haan and Rotmans 2018), allowing that single organization to legitimize themselves, expand their brand to other countries, develop global collaboration brewing partnerships, and engage in conversations with larger retailers and brewers (Hockerts and Wüstenhagen 2009). Interestingly, this suggests that mobilization capacity of the network may be unevenly distributed and that, while extensive relational resources may be helpful to overall IC building, even distribution of mobilization capacity among a full range of actors is not a required element for scaling.

In the recycled water partnership, some interviewees considered brewers as clear stakeholders of the innovation network while others considered brewers simply as educational mediums to demonstrate their recycled water product. The level of investment and knowledge, as well as regulatory barriers, prevents brewers from being able to continue the practice on their own. However, there are signs of the partnerships developed through these experiments creating durable working relationships between the breweries and organizing utilities - preparing overall institutional capacity to improve water (and wastewater) management and use within breweries and their communities moving forward (Prendeville et al., 2018). Further, the experiment network was integrated along existing water and wastewater professional networks that allowed a broader range of stakeholders to apply and test the practice in their communities. This creates a thicker and more integrated web-like network to collaboratively govern sustainability innovation and transition (Khan 2013), and also creates a broader base of knowledge for actors to draw from (Spekkink 2015). This manifested in a formalized Pure Water Brewing Alliance (PWBA) network, as well as the

ability to influence regulations and develop increasing windows of opportunity for the practice.

Though a benefit of IC is that it prepares actor networks for future challenges beyond the initial collaboration (Spekkink 2013, Abreu and Ceglia 2018), in the cases examined it is unclear whether the IC built by either network laid foundation for sustainability practices other than the specific practice experimented on. This was likely related to the dynamics of the transition arena, in which (mostly) one-time partnerships did not allow sufficient interaction for a deeper integration of perspectives around sustainability. Many brewers who participated found the partnerships to be fun experiments, but rarely conceptualized either as a building block for continuing that practice or further integrating cleaner production (CP) practices or eco-innovation in the brewery. Apart from those who already prioritized sustainability in their organizational ethos, only two breweries expressed that the experience had specifically catalyzed further sustainability practices. However, others expressed that it did build an awareness and an openness to sustainability collaborations in the future. This reinforces the findings that SMEs are an open and willing partner for sustainability experimentation but often need institutional support to overcome barriers of adoption (Burch et al., 2016, Quintás et al., 2018).

The potential for this was demonstrated well by the two bread brewing partnerships organized by ZWS. The presence of a government related actor provided legitimacy and action capacity that led to a higher level of commitment from the partner breweries, and a more effective lasting outcome. This fills the important step of empowering actors to develop a niche innovation (Smith and Raven 2012), in this case as a strategic decision by governance systems to utilize experimentation for CE development.

5.3.2 Analysis of Experimentation Characteristics

While both innovation network cases experiment with simple symbiotic exchanges to convert an industrial byproduct into valuable resources for craft breweries, the dynamics of each were fairly different. Though classifying sustainability experiment types requires some oversimplification and there is inevitable overlap between types of experiments, considering the way experiments come to be, who is involved in creating them, and how they are implemented is a useful analytical step to investigating the goals and outcomes of an experiment (Bulkeley and Castan Broto 2013).

The bread beer innovation network was initiated primarily by food system activists who identified an opportunity to reduce food waste and raise awareness of the issue by utilizing surplus bread for beer brewing instead of lower disposal means such as animal feed, compost or landfilling. The development of a social enterprise craft beer organization to drive this cause, and the informal network through which the practice is arising around the UK, suggests these collaborative experiments are primarily grassroots experiments. Sengers considers the characteristics of a grassroots experiment to consist of "networks of activists and organizations generating novel bottom-up solutions for sustainable development; solutions that respond to the local situation and the interests and values of the communities involved. They are thereby motivated by the social needs and ideology" (Sengers et al., 2016).

The recycled water innovation network of collaborative experimentation was primarily initiated by municipal and regional water utilities who identified an opportunity to raise awareness and and build public acceptance of reclaimed water for human consumption as key to a sustainable water future. The deliberate nature of these experiments and role of regime actors show characteristics of strategic or civic experiments using successive

experimentation projects to explore and demonstrate best practices in circular water use. Strategic and civic experiments typically involve more established actors such as government organizations (Bulkeley et al., 2018).

5.3.3 Sociotechnical System and Transition Potential

Both of these experimental interventions take place within the arena of the craft beer sector and its sociotechnical system but are actually driven by actors who are rooted in agricultural and food systems in the case of bread brewing, and in the water sector in the case of recycled water brewing. There is clear overlap as the brewing industry is clearly an impactful industry on the nexus of food, water and energy systems, as was highlighted by interviews with brewers and the intermediary organizations that initiated or facilitated these experiments.

While the bread brewing network does explicitly aim to reduce food waste and some actors think its role is primarily as an educational tool to raise awareness among consumers, as a practice the utilization of recovered bread for brewing is positioned as a niche innovation within the sociotechnical landscape of the beer sector (Geels et al., 2011). While using bread for beer is itself an ancient practice, the emergence in the modern craft beer landscape presents a new operational and institutional practice rather than a niche technology to question the existing paradigm of brewing supply chains (Kalmykova et al., 2018, Brehmer et al., 2018).

The use of recycled water for human consumption, referred to as direct potable reuse (DPR), was found to be a radically new practice for the water sector but with limited potential to radically change the craft beer industry. For most brewers, the recycled water received from their local utilities for these brewing experiments was considered not much different than working with reverse osmosis (RO) water, which has been purified and stripped of mineral content to function as a blank slate from which brewers can build their desired water portfolio. In most cases brewers were essentially recruited as champions for the quality of recycled water, essentially with the reasoning that brewers work with and understand water quality issues and have a customer base open to experimental beers (the difference here being the experimental aspect was more in the sourcing of the water than the type of beer).

Both niche practices have been tested in relatively protected environments in which a community of users were able to refine the process, generate and share knowledge, and influence public perception through repeated experimentation to gain a foothold within the brewing sector (Geels 2018, Bulkeley and Castan Broto 2013). However, the practices differ in terms of their levels of integration within the existing regime and in the requirements for scaling.

The bread brewing network has involved almost entirely civil society actors in a grassroots movement to minimize the environmental impact of bakery and beer businesses through symbiotic resource flows. This is with the exception of the two interventions facilitated by Zero Waste Scotland, the only government aligned actor within the network. Notably, these projects also came with further support and follow-up than others, leading to a more deliberate process and successful outcome of breweries and bakeries continuing the practice on their own. However there are other signs of scaling, seen through the rapid spreading of this practice through increasing experimental bread brew projects, the emergence of full time recovered bread breweries, and the spread of the practice from purely small craft breweries to more established regime actors. This all indicates some potential for the practice to gain stability within the brewing sector, though it would probably remain a niche among craft brewers with higher resource savings potential at more industrial scales.

The recycled water brewing project was a niche practice proposed by regime actors who are deeply aware of the need to identify new practices for sustainable water management in their regions. In this case the breweries participating in recycled water experiments are more willing participants in the project than the driving force. As a deliberate sociotechnical transition experiment, this practice has been supported in protected spaces across an increasingly formalized network of actors including water utilities, academic institutions, private sector engineering and technology partners, and craft brewers. This has come with institutional support to test the practice in a real-world setting, which interviewees expressed was more a matter of testing and building public awareness and receptiveness than the technology. This network of frontrunners within the wastewater regime and supported by exogenous pressures of increasing drought and water insecurity on one hand and increasing public acceptance on the other, have successfully leveraged these brewing demonstrations as a proof of concept in their dialogue with regulatory institutions to create space for direct potable reuse. It seems likely that the technology will continue to be tested and scaled up as utilities and regulators create a stable niche for recycled water consumption in areas with strained water resources.

5.3.4 Applicability of the IC Building Framework

This research project applied the IC building framework to analyze the knowledge resources, relational resources, and mobilization capacity developed across collaborative experimentation networks. This addresses the call in recent research for experimentation analysis to move beyond the individual case study to consider the potential for experimentation networks to lead to new socio-technical practices for sustainability transitions. This study suggests that the IC building framework is well suited to comprehensively analyze the dynamics and outcomes of sustainability experiments.

The ability of distributed innovation networks to test potential innovations in different locations and contexts can provide diverse experimentation environments and learning outcomes for niche development (Sengers et al., 2016). While individual experiment initiatives may achieve varied levels of success, if the ultimate goal is generating social learning for transformative practices then it is important co-produce knowledge from a group of experiments, including successful and less successful examples. If the overall level of IC is increased then the ability of that innovation network to have transformative impact may increase as well, creating further windows of opportunity for action (Spekkink 2015, Abreu and Ceglia 2018).

Though the semi-structured interviews did provide some indications of whether organizational learning occurred, the IC framework applied to the system level does not provide enough depth to understand the quality of learning among participating SMEs. The main indicator of organizational level learning was whether direct sustainability actions were implemented as a result of participating in the experiment (Cerchione et al., 2015, Dieleman 2013). Deeper study of a single experiment initiative may provide more insight on the quality of learning occurring in terms of conceptual and practical knowledge gained.

The IC framework has proven useful to analyze the dynamics and impact of experimentation networks at the innovation system level. The details provided by the framework indicators provide insight on experimentation and transition topics including social learning, network building and collaboration dynamics, and the distributed power to act throughout the field of actors.

However, further testing of the framework should be applied to analyze system-level innovation networks over longer periods of time, and in different sociotechnical systems, to see if levels of IC can be a reliable indicator of transition potential. As the networks studied here were recently developed, it is too early to tell what the eventual impact will be on socio-technical system transitions.

6 Conclusions

This research project applied the institutional capacity building framework to comprehensively analyze the knowledge resources, relational resources, and mobilization capacity developed through collaborative sustainability experimentation arenas. This project fills a number of identified research needs in the field of experimentation for sustainability transitions, including: 1) the need to analyze beyond the individual experiment level to consider dynamics of niche protection and growth; 2) the need for a cohesive analysis of social learning and network building across experimentation networks, and 3) a way to assess transformative potential of experimental governance. The framework was tested on two sustainability innovation networks using industrial symbiosis experiments to explore new methods of value creation and resource reduction related to the craft beer sector, food systems, and water systems, using the following research question and sub-questions:

How did the emergence of collaborative experimentation networks increase the institutional capacity for sustainability transitions and economic circularity within participating craft beer SMEs and their communities?

- *Has social learning for sustainability occurred at the organizational level based on participation in collaborative experiments?*
- *Do actors feel increased capacity to implement the tested practice or other sustainable business model activities as a result of the knowledge and relational resources developed (if any)?*
- *Has sufficient institutional capacity been developed for these innovation networks to scale up the specific practice for socio-technical transformation?*

The two case studies analyzed were niche innovation networks developed around experimentation with use of surplus bread to offset malted barley inputs in craft beer SMEs in the UK, and experimentation with the use of recycled water in brewing in the US.

Findings show that each experimentation network did build overall system IC for niche protection and development. However, the opportunities for further action are unevenly distributed among the networks. In individual experiment initiatives comprising the networks, the organizing actors were able to design the transition arena and problem definition with limited negotiation of a shared vision. In these cases the experiments did contribute to their learning goals but fell short of desired sustainability experimentation outcomes in terms of distributed social learning across the network. In the few cases where experiments were explicitly designed for mutual learning for developing CE practices, actors understood the collective challenge being addressed and were able to integrate the experimental practice into their operations.

The levels of IC developed also show potential for these innovation networks to further develop their niche practices for system transformation.

For the recycled water network, the IC building has led to successive experiments at increasing scales, the development of a formal network to facilitate social learning and niche development, and has already influenced state regulations to permit certain demonstration uses of recycled water for human consumption. This was also accelerated by integration of this experiment network with existing networks, as there are already established working relationships and trust developed among the actors.

The IC developed in the surplus bread brewing network has helped multiple craft breweries adopt bread brewing for their full range of beers, has raised awareness about the potential to utilize food waste as a resource, and has is being explored at various regime levels. The different rates and levels of IC built, and associated transformative potential, are related to the difference in range of actors. The recycled water network benefited from a diverse actor and knowledge base from different sectors and governance levels, whereas the surplus bread network was mostly driven by sustainability focused craft beer organizations. However, the grassroots bread brewing network included strategic communication and marketing around its collaboration experiments that helped elevate experiments to a level of visibility and interest not generally seen in small sustainability initiatives.

The research also confirmed findings suggesting SMEs could be valuable participants of sustainability innovation networks. This was particularly true of craft beer SMEs, who demonstrated an openness to experimentation and knowledge sharing for sustainability. Further, the use of open innovation provides capacity for experimentation and learning for new practices that SMEs would not be able to research and develop on their own. However, the potential for experimentation to lead to actionable learning outcomes in SMEs is dependent on a well-designed partnership. The process should include development of a shared problem definition and potential solution as well as support for the organizations to take immediate action based on the knowledge developed.

In this initial application of IC to experimentation, it appears the framework is well suited to examine the outcomes at the levels of individual collaborative experiments and of experiment networks as they develop. However, the framework would have to be further tested and developed to determine how well levels of IC indicate potential for innovation networks to protect and grow a niche for transformative impact.

6.1 Recommendations

The research and analysis lead to a number of practical and academic recommendations for stakeholders involved in designing, implementing, and studying sustainability experiments generally and for circular economy practices specifically.

- Sustainability governance actors should continue to support experimentation as a means of identifying potential socio-technical innovations and facilitating public discourse, social learning and network building for sustainable transition pathways. The following recommendations will help these processes to be more effective:
    - Utilize existing networks to conduct distributed sustainability experiments with collaborative knowledge production and sharing to provide iterative learning about potential innovations in similar and varied contexts over time. This entails moving beyond single experiments to allow repeated interactions and shared learning among actors through successive experiments.
    - Where possible, experiment networks should include actors from various scales including grassroots and established regime actors to ensure open, multiscalar discourse among actors and leverage a broader mobilization capacity.
    - Set clear practical and learning objectives for sustainability experiments to communicate project goals with all involved actors. Follow up with actors to discuss learning outcomes, which provides experiment evaluation and can act as a form of collaborative and reflective learning in itself. This can include surveys, questionnaires, feedback sessions, etc.

  - Set mandates for established (incumbent) institutional actors to explicitly consider sustainability and innovation goals. This allows such actors to proactively engage with innovation and experiment networks instead of to resist innovation.
  - Prioritize funding for experimental projects that focus on collaboration, scaling, and community demonstration. This provides public engagement and support for sustainability experiments and directs actor goals toward explicit learning for broader sustainability transitions.
  - Ensure that experiments have discursive and educational elements to facilitate a shared vision among actors. This is easier if the experiments can be made to seem locally relevant for actors (such as water experiments in dry states).
  - Engage SMEs in circular economy experiments that showcase the benefits of cleaner production or circular practices in a way that provides mutual education and actionable steps for adopting new practices.

- Further academic research is needed to understand how the dynamics of sustainability experimentation can lead to social learning, network building and increased action capacity. Essentially, the question of how experiments can lead to sociotechnical system and broader sustainability transitions remains of critical importance. Suggestions for further research include:
  - Application of the Institutional Capacity (IC) Building framework to further experiment network case studies at individual experiment levels (including organization/participant learning and collaboratively developed IC) and in aggregate at the experiment network level.
  - Deeper examination of the quality of learning in sustainability experiments, to inform design of experiments for better learning and collective visioning. For a deeper impact it is important to co-produce knowledge across actors in order to create a shared problem definition and vision for action among involved stakeholders.
  - As proposed by Burch et al (2018) and others, further examination is needed of power dynamics at play within experiments
  - Consider mutually beneficial experimentation as way to engage SMEs in CE and sustainability
  - Examine experimentation in terms of place embeddedness and relevance

Bibliography

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

Antikainen, R., Alhola, K., & Jääskeläinen, T. (2017). Experiments as a means towards sustainable societies – Lessons learnt and future outlooks from a Finnish perspective. *Journal of Cleaner Production*, 169, 216–224.

Astbury, J., Bulkeley, H. (2018). Bringing Urban Living Labs to Communities: Enabling Processes of Transformation. In *Urban Living Labs: Experimenting with City Futures,* ed. S. Marvin, H. Bulkeley, L. Mai, K. McCormick, Y.V. Palgan, 106-125. New Yourk: Routledge.

Brewers Association (BA). (2019). National Beer Sales & Production Data. Avalable online: https://www.brewersassociation.org/statistics-and-data/national-beer-stats/ (accessed May 2019).

Baldassarre, B., Calabretta, G., Bocken, N. M. P., & Jaskiewicz, T. (2017). Bridging sustainable business model innovation and user-driven innovation: A process for sustainable value proposition design. *Journal of Cleaner Production*, 147, 175–186.

Beers, P. J., Mierlo, B. van, & Hoes, A.-C. (2016). Toward an Integrative Perspective on Social Learning in System Innovation Initiatives. *Ecology and Society*, 21(1).

Behnam, S., Cagliano, R., & Grijalvo, M. (2018). How should firms reconcile their open innovation capabilities for incorporating external actors in innovations aimed at sustainable development? *Journal of Cleaner Production*, 170, 950–965.

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

Birkmann, J., Garschagen, M., Kraas, F., & Quang, N. (2010). Adaptive urban governance: new challenges for the second generation of urban adaptation strategies to climate change. *Sustainability Science,* 5(2), 185–206.

Blomsma, F. (2018). Collective 'action recipes' in a circular economy – On waste and resource management frameworks and their role in collective change. *Journal of Cleaner Production*, 199, 969–982.

Bocken, N. M. P., Schuit, C. S. C., & Kraaijenhagen, C. (2018). Experimenting with a circular business model: Lessons from eight cases. *Environmental Innovation and Societal Transitions*, 28, 79–95.

Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production*, 65, 42–56.

Bocken, N., Strupeit, L., Whalen, K., & Nußholz, J. (2019). A Review and Evaluation of Circular Business Model Innovation Tools. *Sustainability,* 11(8), 2210.

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

Bocken, Nancy M.P., Miller, K., Weissbrod, I., Holgado, M., & Evans, S. (2017). Business model experimentation for circularity: Driving sustainability in a large international clothing retailer. Economics and Policy of Energy and the Environment (1), 85–122.

Boiral, O., Baron, C., Gunnlaugson, O. (2014). Environmental leadership and consciousness development: a case study among Canadian SMEs. *Journal of Business Ethics* 123: 363-383

Bolton, R., & Hannon, M. (2016). Governing sustainability transitions through business model innovation: Towards a systems understanding. *Research Policy*, 45(9), 1731–1742.

Boon, W. P. C., Moors, E. H. M., & Meijer, A. J. (2014). Exploring dynamics and strategies of niche protection. *Research Policy*, 43(4), 792–803.

Boons, F., & Spekkink, W. (2012). Levels of Institutional Capacity and Actor Expectations about Industrial Symbiosis. *Journal of Industrial Ecology*, 16(1), 61–69.

Boons, F., Spekkink, W., & Mouzakitis, Y. (2011). The dynamics of industrial symbiosis: a proposal for a conceptual framework based upon a comprehensive literature review. *Journal of Cleaner Production*, 19(9–10), 905–911.

Bos, J. J., Brown, R. R., & Farrelly, M. A. (2013). A design framework for creating social learning situations. *Global*

Environmental Change, 23(2), 398–412.

Bosch-Ohlenschlager, S. J. M. van den. (2010). Transition experiments: exploring societal changes towards sustainability. Rotterdam: Erasmus Univ.

Bossle, M. B., Dutra de Barcellos, M., Vieira, L. M., & Sauvée, L. (2016). The drivers for adoption of eco-innovation. *Journal of Cleaner Production*, 113, 861–872.

Bouncken, R. B., & Fredrich, V. (2016). Business model innovation in alliances: Successful configurations. *Journal of Business Research,* 69(9), 3584–3590.

Brehmer, M., Podoynitsyna, K., & Langerak, F. (2018). Sustainable business models as boundary-spanning systems of value transfers. *Journal of Cleaner Production*, 172, 4514–4531.

Brink, E., Wamsler, C., Adolfsson, M., Axelsson, M., Beery, T., Björn, H., Bramyrd, T., Ekelund, N., Jepshon, T., Narvelo, W., Ness, B., Jonsson, K.I., Palo, T., Sjeldrup, M., Stalhammar, S., Thiere, G. (2018). On the road to 'research municipalities': analysing transdisciplinarity in municipal ecosystem services and adaptation planning. *Sustainability Science*, 13(3), 765–784.

Buiatti, S. (2009). Beer Composition: An Overview. In *Beer in Health and Disease Prevention* (pp. 213–225).

Bulkeley, H. (2010). Climate policy and governance: an editorial essay: Climate policy and governance. *Wiley Interdisciplinary Reviews: Climate Change*, 1(3), 311–313.

Bulkeley, H., & Castán Broto, V. (2013). Government by experiment? Global cities and the governing of climate change: Government by experiment? *Transactions of the Institute of British Geographers*, 38(3), 361–375.

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., Marvin, S., McCormick, K., van Steenbergen, F., Voytenko Palgan, Y. (2016). Urban living labs: governing urban sustainability transitions. *Current Opinion in Environmental Sustainability*, 22, 13–17.

Bulkeley, H., Marvin, S., Palgan, Y. V., McCormick, K., Breitfuss-Loidl, M., Mai, L., von Wirth, T., Frantzeskaki, N. (2018). Urban living laboratories: Conducting the experimental city? *European Urban and Regional Studies*

Burch, S., Graham, A., Mitchell, C. (2018). Agency, Space and Partnerships: Exploring key dimensions of urban living labs in Vancouver, Canada. In *Urban Living Labs: Experimenting with City Futures*, ed. S. Marvin, H. Bulkeley, L. Mai, K. McCormick, Y.V. Palgan, 189-209. New Yourk: Routledge.

Burch, S., Andrachuk, M., Carey, D., Frantzeskaki, N., Schroeder, H., Mischkowski, N., & Loorbach, D. (2016). Governing and accelerating transformative entrepreneurship: exploring the potential for small business innovation on urban sustainability transitions. *Current Opinion in Environmental Sustainability*, 22, 26–32.

Cabras, I. (2018). Beer on! The Evolution of Micro-Brewing in the UK. In *Economic Perspectives on Craft Beer: A Revolution in the Global Beer Industry*, ed. C. Garavaglia, J. Swinnen, 373-396. Cham: Springer Nature.

Cabras, I., & Mount, M. P. (2017). How third places foster and shape community cohesion, economic development and social capital: The case of pubs in rural Ireland. *Journal of Rural Studies*, 55, 71–82.

Carley, S., & Yahng, L. (2018). Willingness-to-pay for sustainable beer. *Plos One*, 13(10), e0204917.

Carvalho, A. D. P., Cunha, S. K. da, Lima, L. F. de, & Carstens, D. D. (2017). The role and contributions of sociological institutional theory to the socio-technical approach to innovation theory. *RAI Revista de Administração e Inovação*, 14(3), 250–259.

Cerchione, R., Esposito, E., & Spadaro, M. R. (2015). The Spread of Knowledge Management in SMEs: A Scenario in Evolution. *Sustainability*, 7(8), 10210–10232.

Cheng, C. C. J., Yang, C., & Sheu, C. (2016). Effects of open innovation and knowledge-based dynamic capabilities on radical innovation: An empirical study. *Journal of Engineering and Technology Management*, 41, 79–91.

Chertow, M.R. (2007). 'Uncovering' Industrial Symbiosis. *Journal of Industrial Ecology* 11(1): 11-30.

Colvin, J., Blackmore, C., Chimbuya, S., Collins, K., Dent, M., Goss, J., Ison, R., Roggero, P.P., Seddaiu, G. (2014). In search of systemic innovation for sustainable development: A design praxis emerging from a decade of social learning inquiry. *Research Policy,* 43(4), 760–771.

Danson, M., Galloway, L., Cabras, I., Beatty, C. (2015). Microbrewing and entrepreneurship: the origins, development and integration of real ale breweries in Britain. *International Journal of Entrepreneurship and Innovation Management* 16(2):

135-144.

Davies, A. R., Edwards, F., Marovelli, B., Morrow, O., Rut, M., & Weymes, M. (2017). Making visible: Interrogating the performance of food sharing across 100 urban areas. *Geoforum*, 86, 136–149.

de Coninck, A. Revi, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, J. Ford, S. Fuss, JC. Hourcade, D., Ley, R., Mechler, P., Newman, A., Revokatova, S., Schultz, L., Steg, T., Sugiyama. (2018). Strengthening and implementing the global response. In *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse emission pathways.*

Ley, R. Mechler, P. Newman, A. Revokatova, S. Schultz, L. Steg, T. Sugiyama, (2018). Strengthening and implementing the global response. In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C. In Press

de Haan, F. J., & Rotmans, J. (2018). A proposed theoretical framework for actors in transformative change. *Technological Forecasting and Social Change*, 128, 275–286.

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 Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2018). Eco-innovation in the transition to a circular economy: An analytical literature review. *Journal of Cleaner Production*, 172, 2999–3018.

Dieleman, H. (2007). Cleaner production and innovation theory: Social experiments as a new model to engage in cleaner production. *Revista Internacional de Contaminación Ambiental* 23(2): 79-94

Dieleman, H. (2013). Organizational learning for resilient cities, through realizing eco-cultural innovations. *Journal of Cleaner Production*, 50, 171–180.

Dlouhá, J., Barton, A., Janoušková, S., & Dlouhý, J. (2013). Social learning indicators in sustainability-oriented regional learning networks. *Journal of Cleaner Production*, 49, 64–73.

Dolata, U. (2009). Technological innovations and sectoral change. *Research Policy*, 38(6), 1066–1076.

Drummond, C., McGrath, H., & O'Toole, T. (2018). The impact of social media on resource mobilisation in entrepreneurial firms. *Industrial Marketing Management*, 70, 68–89.

Edmondson, D. L., Kern, F., & Rogge, K. S. (2018). The co-evolution of policy mixes and socio-technical systems: Towards a conceptual framework of policy mix feedback in sustainability transitions. *Research Policy,* 103555.

Edwards, G. A. S., & Bulkeley, H. (2018). Heterotopia and the urban politics of climate change experimentation. *Environment and Planning D: Society and Space*, 36(2), 350–369.

Ehnert, F., Frantzeskaki, N., Barnes, J., Borgström, S., Gorissen, L., Kern, F., Strenchock, L., Egermann, M. (2018). The Acceleration of Urban Sustainability Transitions: A Comparison of Brighton, Budapest, Dresden, Genk, and Stockholm. Sustainability, 10(3), 612.

Ellen Macarthur Foundation. (2013). Towards the Circular Economy.

Elzinga, K.G., Tremblay, C.H., Tremblay, V.J. (2018). In Economic Perspectives on Craft Beer: A Revolution in the Global Beer Industry, ed. C. Garavaglia, J. Swinnen, 55-88. Cham: Springer Nature.

Elzinga, K. G., Tremblay, C. H., & Tremblay, V. J. (2015). Craft Beer in the United States: History, Numbers, and Geography. *Journal of Wine Economics*, 10(3), 242–274. https

European Commission (EC). (2018). Ethics and data protection.

Farla, J., Markard, J., Raven, R., & Coenen, L. (2012). Sustainability transitions in the making: A closer look at actors, strategies and resources. *Technological Forecasting and Social Change*, 79(6), 991–998.

Filho, W., Platje, J., Gerstlberger, W., Ciegis, R., Kääriä, J., Klavins, M., & Kliucininkas, L. (2016). The role of governance in realising the transition towards sustainable societies. *Journal of Cleaner Production*, 113, 755–766.

Fletchall, A. M. (2016). Place-Making Through Beer-Drinking: A Case Study of Montana's Craft Breweries. *Geographical Review*, 106(4), 539–566.

Frantzeskaki, N., & Rok, A. (2018). Co-producing urban sustainability transitions knowledge with community, policy and science. *Environmental Innovation and Societal Transitions*, 29, 47–51.

Frantzeskaki, N., Loorbach, D., & Meadowcroft, J. (2012). Governing societal transitions to sustainability. International Journal of Sustainable Development, 15(1), 19.

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

Fuenfschilling, L., & Truffer, B. (2016). The interplay of institutions, actors and technologies in socio-technical systems — An analysis of transformations in the Australian urban water sector. *Technological Forecasting and Social Change*, 103, 298–312.

Garavaglia, C., & Swinnen, J. F. M. (Eds.). (2018). Economic perspectives on craft beer: a revolution in the global beer industry. Cham, Switzerland: Palgrave Macmillan.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems. *Research Policy*, 33(6–7), 897–920.

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions,* 1(1), 24–40.

Geels, F. W. (2018). Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. *Energy Research & Social Science*, 37, 224–231.

Geels, F. W., & Kemp, R. (2007). Dynamics in socio-technical systems: Typology of change processes and contrasting case studies. *Technology in Society*, 29(4), 441–455.

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

Geels, F. W., & Verhees, B. (2011). Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986). *Technological Forecasting and Social Change*, 78(6), 910–930.

Geels, F., & Deuten, J. J. (2006). Local and global dynamics in technological development: a socio-cognitive perspective on knowledge flows and lessons from reinforced concrete. *Science and Public Policy*, 33(4), 265–275.

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

Gibson, M., & Newsham, P. (2018). Wine and Beer. In *Food Science and the Culinary Arts* (pp. 373–397).

Giuri, P., Munari, F., Scandura, A., & Toschi, L. (2019). The strategic orientation of universities in knowledge transfer activities. *Technological Forecasting and Social Change*, 138, 261–278.

Gliedt, T., Hoicka, C. E., & Jackson, N. (2018). Innovation intermediaries accelerating environmental sustainability transitions. *Journal of Cleaner Production*, 174, 1247–1261.

Gollnhofer, J. F. (2017). Normalising alternative practices: the recovery, distribution and consumption of food waste. *Journal of Marketing Management*, 33(7–8), 624–643.

Gonzalez, R. V. D., & de Melo, T. M. (2018). The effects of organization context on knowledge exploration and exploitation. *Journal of Business Research*, 90, 215–225.

Hansen, T., & Coenen, L. (2015). The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. *Environmental Innovation and Societal Transitions*, 17, 92–109.

Healey 2003 - Place identity and local politics_ analysing initiatives in deliberative governance.doc. (n.d.).

"Healey, P., De Magalhaes, C., Madanipour, A., 1999. Institutional capacity building, urban planning and urban regeneration projects. *Journal of Finnish Social Future Study* 18(3): 117-137.

Hildén, M., Jordan, A., & Huitema, D. (2017). Special issue on experimentation for climate change solutions editorial: The search for climate change and sustainability solutions - The promise and the pitfalls of experimentation. *Journal of Cleaner Production,* 169, 1–7.

Hoalst-Pullen, N., Patterson, M. W., Mattord, R. A., & Vest, M. D. (2014). Sustainability Trends in the Regional Craft Beer Industry. In M. Patterson & N. Hoalst-Pullen (Eds.), *The Geography of Beer* (pp. 109–116).

Hobson, K., & Lynch, N. (2016). Diversifying and de-growing the circular economy: Radical social transformation in a resource-scarce world. *Futures*, 82, 15–25.

Hockerts, K., Wustenhagen, R. (2009). Greening Goliaths versus Emerging Davids. CBS Center for Corporate Social Responsibility

Hojnik, J., & Ruzzier, M. (2016). What drives eco-innovation? A review of an emerging literature. *Environmental Innovation and Societal Transitions*, 19, 31–41.

Hospido, A., Moreira, M. T., & Feijoo, G. (2005). Environmental analysis of beer production. *International Journal of Agricultural Resources, Governance and Ecology*, 4(2), 152.

Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy*, 35(5), 715–728.

Huguenin, A., & Jeannerat, H. (2017). Creating change through pilot and demonstration projects: Towards a valuation policy approach. *Research Policy*, 46(3), 624–635.

Innes, J. E., & Booher, D. E. (1999). Consensus Building and Complex Adaptive Systems: A Framework for Evaluating Collaborative Planning. *Journal of the American Planning Association*, 65(4), 412–423.

Innes, J. E., & Booher, D. E. (2003). The Impact of Collaborative Planning on Governance Capacity. 33.

Jennings, J., Antrobus, K. L., Atencio, S. J., Glavich, E., Johnson, R., Loffler, G., & Luu, C. (2005). "Drinking Beer in a Blissful Mood": Alcohol Production, Operational Chains, and Feasting in the Ancient World. *Current Anthropology*, 46(2), 275–303.

Johnson, M. P. (2017). Knowledge acquisition and development in sustainability-oriented small and medium-sized enterprises: Exploring the practices, capabilities and cooperation. *Journal of Cleaner Production,* 142, 3769–3781.

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

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

Khan, J. (2013). What role for network governance in urban low carbon transitions? *Journal of Cleaner Production*, 50, 133–139.

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

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, 45(1), 205–217.

Kivimaa, P., Boon, W., Hyysalo, S., & Klerkx, L. (2018). Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. *Research Policy*.

Kivimaa, P., Hyysalo, S., Boon, W., Klerkx, L., Martiskainen, M., & Schot, J. (2019). Passing the baton: How intermediaries advance sustainability transitions in different phases. *Environmental Innovation and Societal Transitions.*

Klerkx, L., & Aarts, N. (2013). The interaction of multiple champions in orchestrating innovation networks: Conflicts and complementarities. *Technovation*, 33(6–7), 193–210.

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Berg, A, Boons, F., Funfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kiviima, P., Martiskainen, M., McMeekin, A., Muhlemeier, M.S., Nykvist, B., Pel, B., Raven, R., Rohracher, H., Sanden, B., Schot, J., Sovacool, B., Turnheim, B., Welch, D., Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions.*

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

"Lambert, A.J.D., Boons, F.A., 2002. Eco-industrial parks: stimulating sustainable development in mixed industrial parks. *Technovation* 22 (8): 471-484.

Levänen, J., Lyytinen, T., & Gatica, S. (2018). Modelling the Interplay Between Institutions and Circular Economy Business Models: A Case Study of Battery Recycling in Finland and Chile. *Ecological Economics*, 154, 373–382.

Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. *Sustainability*, 8(1), 43.

Li, Q., Wang, J., & Liu, C. (2017). Beers. In *Current Developments in Biotechnology and Bioengineering* (pp. 305–351).

Loorbach, D., & Rotmans, J. (2006). Managing Transitions for Sustainable Development. In X. Olsthoorn & A. J. Wieczorek (Eds.), *Understanding Industrial Transformation* 44: 187–206.

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

Markard, J., Wirth, S., & Truffer, B. (2016). Institutional dynamics and technology legitimacy – A framework and a case study on biogas technology. *Research Policy*, 45(1), 330–344.

Marra, A., Mazzocchitti, M., Sarra, A. (2018). Knowledge sharing and scientific cooperation in the design of research-based policies; The case of the circular economy. *Journal of Cleaner Production* 194: 800-812.

Marvin, S., Bulkeley, H., Mai, L., McCormick, K., Palgan, Y.V. (2018). Introduction. In Urban Living Labs: Experimenting with City Futures, ed. S. Marvin, H. Bulkeley, L. Mai, K. McCormick, Y.V. Palgan, 1-17. New Yourk: Routledge.

Matschoss, K., & Heiskanen, E. (2017). Making it experimental in several ways: The work of intermediaries in raising the ambition level in local climate initiatives. *Journal of Cleaner Production*, 169, 85–93.

Mirata, M., & Emtairah, T. (2005). Industrial symbiosis networks and the contribution to environmental innovation. *Journal of Cleaner Production*, 13(10–11), 993–1002.

"Monaghan, A. (2017). Craft beer boom pushes number of UK breweries past 2,000. The Guardian. 23 October 2017. Available online: https://www.theguardian.com/lifeandstyle/2017/oct/23/craft-beer-boom-pushes-numberof-

uk-breweries-past-2000. (Accessed April 2019).

Mossberg, J., Söderholm, P., Hellsmark, H., & Nordqvist, S. (2018). Crossing the biorefinery valley of death? Actor roles and networks in overcoming barriers to a sustainability transition. *Environmental Innovation and Societal Transitions*, 27, 83–101.

Murphy, J. T. (2015). Human geography and socio-technical transition studies: Promising intersections. *Environmental Innovation and Societal Transitions*, 17, 73–91.

Nelson, M. (2005). The Barbarian's Beverage: A History of Beer in Ancient Europe. Abdingdon: Routledge

Ness, B. (2018). Beyond the Pale (Ale): An Exploration of the Sustainability Priorities and Innovative Measures in the Craft Beer Sector. *Sustainability*, 10(11), 4108.

Niero, M., Hauschild, M. Z., Hoffmeyer, S. B., & Olsen, S. I. (2017). Combining Eco-Efficiency and Eco-Effectiveness for Continuous Loop Beverage Packaging Systems: Lessons from the Carlsberg Circular Community: Eco-Efficiency and Eco-Effectiveness of Packaging. *Journal of Industrial Ecology*, 21(3), 742–753.

Olajire, A. A. (2012). The brewing industry and environmental challenges. *Journal of Cleaner Production*. 1-21.

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

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, 19(3), 354–365.

Pahl-Wostl, C., Becker, G., Knieper, C., & Sendzimir, J. (2013). How Multilevel Societal Learning Processes Facilitate Transformative Change: A Comparative Case Study Analysis on Flood Management. *Ecology and Society*, 18(4).

Palgan, Y. V., & McCormick, K. (2016). Biorefineries in Sweden: Perspectives on the opportunities, challenges and future: Biorefineries in Sweden. *Biofuels, Bioproducts and Biorefining*, 10(5), 523–533.

Patterson, M.W., Hoalst-Pullen, N. (2014). Geographies of Beer. In *The Geography of Beer: Regions, Environment, and Societies*, ed. M.W. Patterson, N. Hoalst-Pullen, 1-5. Dordrecht: Springer.

Patterson, J., Schulz, K., Vervoot, J., can der Hel, S., Widerberg, O., Adler, C., Hurblert, M., Anderton, K., Sethi, M., Barau, A. (2017). Exploring the governance and politics of transformations toward sustainability. *Environmental Innovation and Societal Transitions* 24: 1-16.

Patterson, M. (Ed.). (2014). The geography of beer: regions, environment, and societies. Dordrecht: Springer.

Perri, Bellamy, C. (2011). Principles of Methodology. In *Research Design in Social Science*, Sage Publications.

Pigosso, D. C. A., Schmiegelow, A., & Andersen, M. M. (2018). Measuring the Readiness of SMEs for Eco-Innovation and Industrial Symbiosis: Development of a Screening Tool. *Sustainability*, 10(8), 2861.

Powells, G., Bell, S., Judson, E. P., Lyon, S. M., Wardle, R., Capova, K. A., & Bulkeley, H. (2016). Fostering active network management through SMEs' practises. *Energy Efficiency*, 9(3), 591–604.

Prendeville, S., Cherim, E., & Bocken, N. (2018). Circular Cities: Mapping Six Cities in Transition. *Environmental Innovation and Societal Transitions*, 26, 171–194.

Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of Cleaner Production*, 179, 605–615.

Quintás, M. A., Martínez-Senra, A. I., & Sartal, A. (2018). The Role of SMEs' Green Business Models in the Transition to a Low-Carbon Economy: Differences in Their Design and Degree of Adoption Stemming from Business Size. *Sustainability*, 10(6), 2109.

Raven, R., Kern, F., Verhees, B., & Smith, A. (2016). Niche construction and empowerment through socio-political work. A meta-analysis of six low-carbon technology cases. *Environmental Innovation and Societal Transitions*, 18, 164–180.

Reid, N., & Gatrell, J. D. (2017). Craft Breweries and Economic Development: Local Geographies of Beer. *Polymath: An Interdisciplinary Arts and Sciences Journal* 21: 90-110.

Rettie, R., Burchell, K., & Riley, D. (2012). Normalising green behaviours: A new approach to sustainability marketing. *Journal of Marketing Management*, 28(3–4), 420–444.

Ritzén, S., & Sandström, G. Ö. (2017). Barriers to the Circular Economy – Integration of Perspectives and Domains. *Procedia CIRP*, 64, 7–12.

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papdelis, S., Hirschnitz-Garbers, M., Topi, C. (2016). Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers. *Sustainability* 8: 1212

Saavedra, Y. M. B., Iritani, D. R., Pavan, A. L. R., & Ometto, A. R. (2018). Theoretical contribution of industrial ecology to circular economy. *Journal of Cleaner Production,* 170, 1514–1522.

Sandiford, P. J., & Divers, P. (2011). The public house and its role in society's margins. *International Journal of Hospitality Management,* 30(4), 765–773.

Schnell, S. M., & Reese, J. F. (2014). Microbreweries, Place, and Identity in the United States. In M. Patterson & N. Hoalst-Pullen (Eds.), *The Geography of Beer* (pp. 167–187).

Sengers, F., Spath, P., Raven, R. (2018). Smart City Construction: Towards an analytical framework for smart urban living labs. In Urban Living Labs: Experimenting with City Futures, ed. S. Marvin, H. Bulkeley, L. Mai, K. McCormick, Y.V. Palgan, 74-88. New Yourk: Routledge.

Sengers, F., Wieczorek, A. J., & Raven, R. (2016). Experimenting for sustainability transitions: A systematic literature review. *Technological Forecasting and Social Change.*

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.

Shears, A. (2014). Local to National and Back Again: Beer, Wisconsin & Scale. In The Geography of Beer: Regions, Environment, and Societies, ed. M.W. Patterson, N. Hoalst-Pullen, 45-56. Dordrecht: Springer.

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

Sol, J., Beers, P. J., & Wals, A. E. J. (2013). Social learning in regional innovation networks: trust, commitment and reframing as emergent properties of interaction. *Journal of Cleaner Production*, 49, 35–43.

Sousa-Zomer, T. T., Magalhães, L., Zancul, E., Campos, L. M. S., & Cauchick-Miguel, P. A. (2018). Cleaner production as an antecedent for circular economy paradigm shift at the micro-level: Evidence from a home appliance manufacturer. *Journal of Cleaner Production*, 185, 740–748.

Spekkink, W. (2013). Institutional capacity building for industrial symbiosis in the Canal Zone of Zeeland in the Netherlands: a process analysis. *Journal of Cleaner Production*, 52, 342–355.

Spekkink, W. (2015). Building capacity for sustainable regional industrial systems: an event sequence analysis of developments in the Sloe Area and Canal Zone. *Journal of Cleaner Production*, 98, 133–144.

Taylor, A., Cocklin, C., Brown, R. (2012). Fostering environmental champions: A process to build their capacity to drive change. *Journal of Environmental Management* 98: 84-97.

Taylor, A., Cocklin, C., Brown, R., & Wilson-Evered, E. (2011). An investigation of champion-driven leadership processes. *The Leadership Quarterly*, 22(2), 412–433.

Tesco and Society. (2014). Food Waste Hotspots. Available online: https://www.tescoplc.com/assets/files/cms/Resources/Food_waste/T_S_Hotspots_190514v3.pdf (accessed May 2019).

Thurnell-Read, T. (2014). Craft, tangibility and affect at work in the microbrewery. *Emotion, Space and Society*, 13, 46–54.

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.

Tukker, A., Emmert, S., Charter, M., Vezzoli, C., Sto, E., Munch Andersen, M., … Lahlou, S. (2008). Fostering change to sustainable consumption and production: an evidence-based view. *Journal of Cleaner Production*, 16(11), 1218–1225.

van den Heiligenberg, H. A. R. M., Heimeriks, G. J., Hekkert, M. P., & van Oort, F. G. (2017). A habitat for sustainability experiments: Success factors for innovations in their local and regional contexts. *Journal of Cleaner Production*, 169, 204–215.

van Mierlo, B., & Beers, P. J. (2018). Understanding and governing learning in sustainability transitions: A review. *Environmental Innovation and Societal Transitions.*

van Mierlo, B., Leeuwis, C., Smits, R., & Woolthuis, R. K. (2010). Learning towards system innovation: Evaluating a systemic instrument. *Technological Forecasting and Social Change*, 77(2), 318–334.

van Mossel, A., van Rijnsoever, F. J., & Hekkert, M. P. (2018). Navigators through the storm: A review of organization theories and the behavior of incumbent firms during transitions. *Environmental Innovation and Societal Transitions*, 26, 44–63.

Van Poeck, K., Östman, L., & Block, T. (2018). Opening up the black box of learning-by-doing in sustainability transitions. *Environmental Innovation and Societal Transitions.*

van Popering-Verkerk, J., & van Buuren, A. (2017). Developing collaborative capacity in pilot projects: Lessons from three Dutch flood risk management experiments. *Journal of Cleaner Production*, 169, 225–233.

Vergragt, P.J., Dendler, L., de Jong, M., Matus, K. (2016). Transitions to sustainable consumption and production in cities. *Journal of Cleaner Production* 134: 1-12

Voytenko, Y., McCormick, K., Evans, J., & Schliwa, G. (2016). Urban living labs for sustainability and low carbon cities in Europe: towards a research agenda. *Journal of Cleaner Production*, 123, 45–54.

Wang, Q., Deutz, P., & Chen, Y. (2017). Building institutional capacity for industrial symbiosis development: A case study of an industrial symbiosis coordination network in China. *Journal of Cleaner Production*, 142, 1571–1582.

Water Environment Federation (WEF). Pure Water Brewing Alliance. Available online: https://www.wef.org/purewaterbrewingalliance (accessed May 2019).

Weiland, S., Bleicher, A., Polzin, C., Rauschmayer, F., & Rode, J. (2017). The nature of experiments for sustainability transformations: A search for common ground. *Journal of Cleaner Production*, 169, 30–38.

Wells, P. (2016). Economies of Scale Versus Small Is Beautiful: A Business Model Approach Based on Architecture, Principles and Components in the Beer Industry. *Organization & Environment*, 29(1), 36–52.

Wittmayer, J. M., Avelino, F., van Steenbergen, F., & Loorbach, D. (2017). Actor roles in transition: Insights from sociological perspectives. *Environmental Innovation and Societal Transitions*, 24, 45–56.

Xie, X., Wang, L., & Zeng, S. (2018). Inter-organizational knowledge acquisition and firms' radical innovation: A moderated mediation analysis. *Journal of Business Research*, 90, 295–306.

Yang, W., Zhou, Q., Yu, X., Wang, D., & Li, H. (2019). How to facilitate knowledge collaboration in OCs: An integrated perspective of technological and institutional measures. *Technological Forecasting and Social Change*, 138, 21–28.

Yoon, B., Shin, J., & Lee, S. (2016). Open Innovation Projects in SMEs as an Engine for Sustainable Growth. *Sustainability*, 8(2), 146.