Urban Experimentation in Support of Sweden's Sustainability Transition

A Case Study of Brunnshög in Lund

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LUCSUS
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Abstract:

The number of people living in urban areas has increased significantly over the past few decades. As such, cities have become centers for population and economic growth. These two factors, however, are also the most significant drivers of fossil fuel related CO_2 emissions. Additionally, urban services contribute to dominant socio-technical systems that are inherently unsustainable, path dependent, and locked-in. Such systems are typically categorized by incremental change, which is not sufficient to address sustainability challenges. Thus, some cities have focused on becoming loci for urban experimentation aimed at revealing sustainable system alternatives that may induce more radical change. In this sense, cities are not only major contributors to climate change, but important areas for sustainability transitions.

Sweden has experienced high rates of urbanization and also strives for sustainable development. Therefore, I have chosen to explore urban experimentation for sustainability within this country by analyzing the developing district of Brunnshög, located in Lund. In this study, I explore how an urban experiment may attempt to challenge dominant socio-technical systems in Lund and how successful these approaches may be at contributing to the larger transition towards sustainability. The multi-level perspective is used to investigate the extent to which Brunnshög's niche-innovations may contribute to the evolution of a specific transition pathway within the city.

This case study reveals that niche-innovations being developed within Brunnshög primarily target four socio-technical systems within the dominant regime: transportation, energy and heating, waste management, and food production. Additionally, landscape pressure is exerted by a national, eco-modern focus on sustainability, as well as growing global awareness that radical action must be taken to sufficiently mitigate climate change. The analysis reveals that Brunnshög, as an urban experiment, is contributing to the current transformation transition path evident within Lund. However, there is potential for this path of transformation to shift to one of reconfiguration. Urban experiments, like Brunnshög, are necessary for providing the protected space needed for this to happen. Brunnshög's unfolding development must be followed over the next couple decades to decisively determine how its niche-innovations impact Lund's transition towards sustainability.

Keywords: Sustainable urban development, socio-technical systems, multi-level perspective, transition pathways, urban experiment, Brunnshög

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List of Abbreviations

GHG	Greenhouse Gas
LTDH	Low Temperature District Heating
MLP	Multi-Level Perspective
RQ1	Research Question 1
RQ2	Research Question 2
STS	Socio-Technical Systems
SES	Socio-Ecological Systems

1 Introduction

1.1 Problem Framing

Earth's temperature is expected to rise 1.5°C above pre-industrial levels by 2030 if immediate action is not taken to significantly reduce greenhouse gas (GHG) emissions (IPCC, 2018). Current warming trends are already causing sea-level rise, heat stress, and extreme weather events globally (Revi et al., 2014). As warming increases, so too will the severity of these trends (Revi et al., 2014). Furthermore, humans' substantial contribution to global warming and climate change is undeniable, as human activity is responsible for about 1.0°C of Earth's temperature rise above pre-industrial levels (IPCC, 2018). This is largely due to increases in fossil fuel use and industrial processes, which are driven by economic and population growth (IPCC, 2014).

The impacts of climate change are concentrated in urban areas, which puts infrastructure systems, the built environment, and ecosystem services at risk (Revi et al., 2014). However, urban areas are also significant contributors to the problem itself. Cities are centers for resource demand and providers of basic services (Loorbach & Shiroyama, 2016). This includes demand for energy, food, water, and shelter, as well as waste management, healthcare, and education (Loorbach & Shiroyama, 2016). Globally, action taken within cities accounts for nearly 75 percent of total resource consumption and 70 percent of energy-related GHG emissions (Fuenfschilling et al., 2019; Loorbach & Shiroyama, 2016). Thus, cities have become the largest contributors to negative environmental impacts (Loorbach & Shiroyama, 2016). Recent and projected urbanization trends are also worrisome. As of 2018, 55 percent of all people on Earth were living in urban areas and by 2050, 68 percent of all people are expected to be inhabiting cities (United Nations et al., 2019). This population growth will continue to drive increases in fossil fuel emissions if nothing changes. Thus, cities must drive sustainable action and they are uniquely situated to do so since they are also centers for sustainability innovation and societal progress (Loorbach & Shiroyama, 2016). Consequently, they have the potential to drive more sustainable behavior and have been identified in the literature as an important area for sustainability transitions (Fuenfschilling et al., 2019).

Sustainability transitions occur when dominant socio-technical systems (STS) shift to a more sustainable form (Geels, 2011). STS deliver societal functions (Geels et al., 2017a) and dominant STS within cities center around urban services, such as transportation and energy supply, which are inherently unsustainable (Loorbach & Shiroyama, 2016; Markard et al., 2012). A failure to transition to environmentally, socially, and economically sustainable STS will lead to further global warming and worsening climate change. However, these transitions have not been known to come about easily, and incremental, rather than radical, change is the norm (Markard et al., 2012). Unfortunately, incremental change will not be sufficient in addressing sustainability challenges (Markard et al., 2012). In a search for sustainable system alternatives, cities have become loci for experimentation (Evans, 2016). Socio-technical experimentation involves introducing "alternative technologies and practices in order to purposively re-shape social and material realities" (Sengers et al., 2019, p. 154). These experiments may "develop and align into a new, potentially more sustainable socio-technical configuration that, if diffused more broadly, will radically alter the existing system" (Fuenfschilling et al., 2019, p. 220). Therefore, it is important to better understand how urban experimentation is impacting sustainability transitions within cities today.

Sweden is globally recognized for striving to develop sustainably (Hilding-Rydevik et al., 2011; Midttun & Olsson, 2018). Their urbanization level also surpassed Europe's 2050 projection of 83.7 percent in 2018 (*Developments and Forecasts on Continuing Urbanisation*, 2018; *World Urbanization Prospects - Population Division - United Nations*, n.d.). As a response to rapid urbanization and the threat of climate change, the government extended financial support in 2008 to projects that aimed to redevelop or newly construct urban areas in ways that would reduce GHG emissions and apply innovative and novel solutions (The Delegation for Sustainable Cities, n.d.). Sustainable Knowledge City Lund NE was one such project, which is closely connected to the development of Brunnshög in Lund (Boverket, 2015). The planning and development of Brunnshög has continued since then and now the project aims to be a European best practice example that demonstrates how to take responsibility locally for the global challenge that is climate change (Lund Municipality, 2019). Thus, this thesis will focus on urban experimentation within Sweden using the newly developing district of Brunnshög, Lund as a case study.

1.2 Research Questions

The purpose of this thesis is to gain a better understanding of how urban experiments may attempt to challenge dominant socio-technical systems in Sweden and how successful these approaches may be at contributing to the country's larger transition towards sustainability. This study will explore the capacity of urban experiments in Sweden to challenge dominant socio-technical systems and influence a larger sustainability transition by answering the following research questions:

1. *How do Brunnshög's proposed innovations intend to challenge dominant socio-technical systems?*
2. *What potential does Brunnshög's development have to contribute to the sustainability transition in Lund?*

Chapter two theoretically frames this report through an introduction to sustainability transition studies, which encompasses urban experimentation, as well as the multi-level perspective framework and its associated transition pathways. The research method follows in chapter three, after which the case study is presented in chapter four. Further results and an analysis are included in chapter five. Finally, a discussion is provided in chapter six, in which the research questions are clearly answered, the application of the multi-level perspective framework to this case study is reflected upon, and suggestions for future research are presented.

1.3 Relevance to Sustainability Science

Sustainability science attempts to understand interactions between nature and society, as well as society's capacity to ensure these interactions are sustainable (Kates et al., 2001). As such, Kates et al. (2001) proposes that research concerning sustainability science should center around exploring not only the "fundamental character of interactions between nature and society," but also "society's capacity to guide those interactions along more sustainable trajectories" (p. 641). The latter is exactly what the interdisciplinary field of sustainability transitions attempts to do. Through the construction of various theoretical frameworks, this field explores how transitions towards sustainability can be characterized, how they can be effectively managed, and ultimately how we can encourage them to occur at a faster rate than is currently seen in the world today (Loorbach et al., 2017). This thesis draws extensively from sustainability transition studies in developing a theoretical frame and is thus, closely aligned with the principles and aims of sustainability science.

Additionally, sustainability science is characterized as transdisciplinary, problem driven and action oriented (Spangenberg, 2011). Sustainability science is not an autonomous field or discipline. Instead, a core strength is its capacity for bringing people together across disciplines to address common sustainability challenges in practical ways (Clark & Dickson, 2003). The Brunnshög project exemplifies these ideals. Multiple stakeholders, from government bodies to the business sector to educational institutions and research facilities, and even everyday citizens have been included in some aspect of the development process (personal communication, February 28, 2020). All these stakeholders are working towards creating a space that is more environmentally, economically, and socially sustainable (Lund Municipality, 2012a). Through the careful design of new technologies and the built environment, more sustainable action can be facilitated and made central to everyday living (Lund Municipality, 2018).

Using the multi-level perspective framework and its associated transition pathways to analyze this case provides a clearer understanding of how action taken in Brunnshög may further the sustainability goals of the city and exemplifies the potential for local actions to contribute to a larger sustainability transition.

2 Theoretical Framing

A focus has been placed on the development of urban responses as a means of transitioning towards local and global sustainability for both research and policy (Wolfram & Frantzeskaki, 2016). Within literature discussing cities and systemic change for sustainability, two ontologies have been identified: socio-technical systems (STS) and social-ecological systems (SES) (Wolfram & Frantzeskaki, 2016). The STS ontology recognizes societal change as a function of co-evolving technologies, institutions, and practices (Wolfram & Frantzeskaki, 2016). This has resulted in a high interest in understanding how to "overcome the path-dependency and high inertia of existing STS that resist necessary sustainability innovations" (Wolfram & Frantzeskaki, 2016, p. 4). This interest helped inform the development of the multi-level perspective (MLP) framework, among others (Markard et al., 2012). On the other hand, the SES ontology has a bigger concern "for governance innovations, experimentation and social learning" based on resilience theory and focuses on identifying "vulnerabilities, unsustainable performances and dynamics of change" (Wolfram & Frantzeskaki, 2016, pp. 5–6). This thesis aligns with the STS ontology and utilizes the MLP, which is the most widely adopted conceptual frame within literature relating cities to systemic change for sustainability (Wolfram & Frantzeskaki, 2016).

This chapter begins with an overview of sustainability transition studies in section 2.1. This is followed by an introduction to the MLP framework in section 2.2 and an overview of experimentation in section 2.3. Finally, this chapter concludes with a summary of different transition pathways in section 2.4.

2.1 Overview of Sustainability Transition Studies

The STS ontology and its associated frameworks form the core of sustainability transition studies (Markard et al., 2012), a field of study that emerged in the 1990's (Sengers et al., 2019), which attempts to understand how transitions for sustainability come about and how to push transitions to move faster (Loorbach et al., 2017). Thus, a foundational concept of transition studies is the idea that unsustainable behavior is inherent to and driven by dominant STS, which are influenced by their societal and environmental surroundings (Loorbach & Shiroyama, 2016). For instance, "established technologies are highly intertwined with user practices and life styles, complementary technologies, business models, value chains, organizational structures, regulations, institutional structures, and even political structures"(Markard et al., 2012, p. 955). In other words, technology is integrated within and supported by social dimensions. This phenomenon, known as lock-in, alludes to the fact that dominant STS rarely experience radical changes, but rather incremental change (Markard et al., 2012).

2.2 Multi-Level Perspective

The MLP is a well-developed, abstract analytical framework commonly used to describe and understand socio-technical sustainability transitions (Geels, 2002; Geels & Schot, 2010; Markard et al., 2012). It is a process theory, which indicates that outcomes are explained “as the result of temporal sequences of events, timing and conjunctures of event-chains” (Geels & Schot, 2007, p. 414), where chains of events are processes orchestrated by situated actors. Moreover, this framework is based on the notion that societal challenges, such as climate change, can only be successfully addressed through deep-structural change (Geels, 2011).

The MLP framework relates three analytical levels: the niche, the regime, and the landscape (Geels, 2002), which broadly encompass the relationships between technology, politics, economics, and culture (Geels, 2011). The interactions between these levels determine how transitions develop (Geels & Schot, 2007). Furthermore, interactions are characterized as non-linear (Geels, 2011), complex, and multi-dimensional (Geels, 2010).

The socio-technical regime conceptualizes the lock-in and path dependency of a dominant socio-technical system, like energy or transportation (Geels & Schot, 2010). Essentially, cognitive, regulative, and normative rules steer the actions taken by a wide range of actors and the interactions between these actors builds mutually dependent networks. This ultimately leads to the lock-in and path dependency of socio-technical systems (Geels & Schot, 2010). This process of stabilization is analytically explained by the regime concept (Geels, 2002). Thus, every socio-technical system is associated with its own regime (Geels, 2004). As illustrated in Figure 1, the interdependencies between networks within a regime can be further conceptualized by six sub-regimes: user preferences, infrastructure, science, policy, culture, and technology (Geels, 2004, 2011). In order for socio-technical systems to transition, a regime shift must occur (Geels, 2011). This shift is complex, occurs over longer periods of time, and is driven by many actors (Geels, 2011).

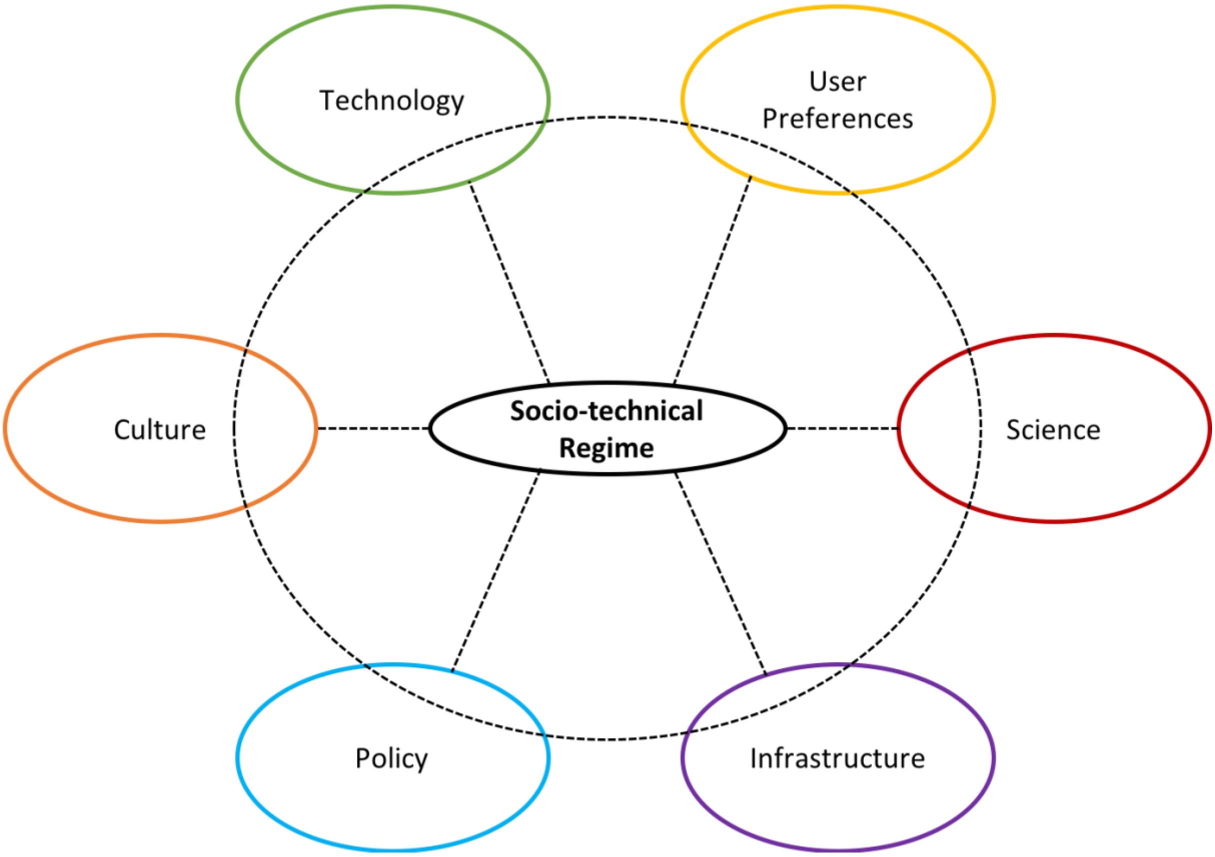

Figure 1. Depiction of the socio-technical regime and its interdependent and co-evolving sub-regimes (Geels, 2004). Throughout papers written about the multi-level perspective framework, sub-regime names shift and change (Geels, 2004, 2011; Geels et al., 2017a, 2017b; Geels & Schot, 2010). Common sub-regimes are represented in this figure. Figure adapted and created by author.

The niche is a protected space where radical innovations – in other words, innovations differing greatly from those which exist within regimes – may develop (Geels, 2011). Niche actors hope that these innovations will either replace regimes or be incorporated into them (Geels, 2011). Ultimately, niches "provide the seeds for systemic change" and are therefore imperative for transitions (Geels, 2011, p. 27).

Lastly, the landscape is the environment in which the niche and regime levels interact but cannot influence in the short term (Geels, 2011; Geels & Schot, 2007). As such, and as seen in Figure 2, it is the most stable analytical level. This environment may be categorized by "demographical trends, political ideologies, societal values, and macro-economic patterns" (Geels, 2011, p. 28).

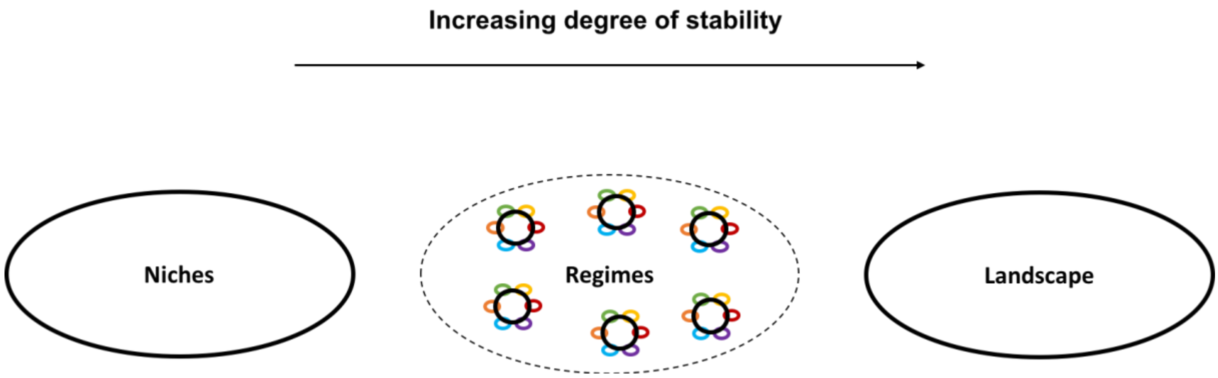

Figure 2. Relative degree of stability between the multi-level perspective framework's analytical levels (Geels, 2011). Early work from Geels on the MLP depicts the three levels as a nested hierarchy (Geels, 2002, 2004). However, Geels (2011) retracts this conceptualization and amends that the levels "refer to different degrees of stability, which are not necessarily hierarchical" (p. 37). More specifically, the stability of local practices (within the regimes and niches) "relate to differences in scale and the number of actors" involved (Geels, 2011, p. 37). Figure adapted and created by author.

2.3 Experimentation

2.3.1 Defining Experimentation

Another central concept within sustainability transitions studies is experimentation (Sengers et al., 2019). Broadly, experimentation can be "conceptualized as an inclusive, practice-based and challenge-led initiative designed to promote system innovation through social learning under conditions of uncertainty and ambiguity" (Sengers et al., 2019, p. 161). In line with this definition, Sengers et al. (2019) also specifies the following five attributes as central to experimentation:

1. The experiment must have a "socio-technical" aspect. In other words, a new technology or social practice must be introduced into society.
2. Established socio-technical systems are central to the way we currently live our lives. Thus, these experiments must provide initiatives which encourage system innovation that may lead to structural change.
3. The new technologies and social practices must address persistent societal problems that are related to the established socio-technical systems and have a normative orientation towards sustainability. This means that initiatives are challenge-led.
4. Experimentation must be inclusive, so that stakeholders are diverse and working towards social learning in relation to the new socio-technical configuration.
5. Experiments are practice-based, which means "a group of diverse social actors team up to test something new in a dynamic real-life social context with the eventual aim to achieve a societal transformation" (Sengers et al., 2019, p. 161).

There are six different conceptualizations of experimentation within sustainability transitions studies. They include niche experiments, bounded socio-technical experiments, grassroots experiments, transition experiments, sustainability experiments, and urban experiments (Sengers et al., 2019). However, urban experimentation will be the focus of this thesis as it is considered to be a prominent method for transforming the urban condition during this century (Evans, 2016).

Urban experimentation can be further segmented. Bulkeley and Castán Broto (2013) categorize urban experiments in three different ways: (1) governance experiments, (2) experiments relating to socio-technical systems and transformation, and (3) "strategic" experiments that focus on testing technical innovation through "living laboratories." I adopt the second conceptualization, as it is informed by the MLP (Bulkeley & Castán Broto, 2013), and thus, aligns with my conceptual frame. Within this conceptualization, urban experiments are seen as either processes of innovation where new technical solutions are refined or as experimental projects that are central to the creation of niches (Bulkeley & Castán Broto, 2013). This distinction has to do with a divide between technical and social innovation respectively. I will attempt to integrate these two perspectives: I argue that the development of Lund's new city district, Brunnshög, is in itself an urban experiment where both technical and social innovations take place. This urban experiment has resulted in the on-going construction of a built environment where innovation is politically encouraged and socially accepted, in other words a niche. Brunnshög provides a protected space for processes of both social and technical innovation, which may eventually challenge dominant socio-technical regimes in the city.

2.3.2 Epistemologies of Urban Experimentation

Four research epistemologies exist within studies relating cities to systemic change for sustainability (Wolfram & Frantzeskaki, 2016). Within the context of this thesis, these epistemologies classify how an urban experiment may approach systemic change for sustainability. However, only three relate to the STS ontology: (1) transforming urban mechanisms and political ecologies, (2) configuring urban innovation systems for green economies, and (3) empowering urban grassroots niches and social innovation (Wolfram & Frantzeskaki, 2016). These epistemologies have been substantiated empirically and conceptually and are partially based on seven basic drivers of societal change: political, economic, ecological, social, cultural, technological, and demographic (Wolfram & Frantzeskaki, 2016). A summary of these epistemologies is provided in Table 1.

Within the first epistemology, Wolfram & Frantzeskaki (2016) note that local government and infrastructure and technology providers are powerful stakeholders who use place based, socio-technical experimentation to explore new ways of providing urban energy, water, waste, and transport management. Their actions prioritize a reduction of the city's carbon and ecological footprints alongside continued access to resources that support economic growth, protect local assets, and uphold present living standards. Other stakeholders, including industry, NGOs, and citizens, may be involved in testing new technologies, services, and usages within an urban area. Focus is given to STS that influence material and energy flows within cities and multi-level governance. The primary drivers of change within this epistemology can be characterized as political, economic, ecological, and technological (Wolfram & Frantzeskaki, 2016).

Within the second epistemology, Wolfram & Frantzeskaki (2016) emphasize production and consumption as primary concerns. There is a strong focus on “greening” the economy. Stakeholders include government agencies, industry, subject matter experts, and academic institutions. Their shared values and “cooperation culture” allow them to partner in ways that increase their competitiveness and reduce the resource intensity of some products and services. Change for sustainability is thus promoted “through local innovation systems for selected markets and socio-technical practices anchored in cities” (Wolfram & Frantzeskaki, 2016, pp. 10–11). The primary drivers of change within this epistemology can be characterized as economic, ecological, and technological. These are complemented slightly by social and cultural drivers of change (Wolfram & Frantzeskaki, 2016).

Within the third epistemology, Wolfram & Frantzeskaki (2016) emphasize that change for sustainability is driven by the application of a variety of approaches led by civil society actors within cities. Their actions stem from environmental concerns, are ethically justifiable, and serve to meet individual and group needs. Initiatives may be made within the areas of food, education, health, green space, and renewable energy, among others. Thus, there is often integration of socio-technical and socio-ecological initiatives. There is also a focus on scaling up initiatives. Ultimately, the transformative potential of initiatives within this epistemology is reliant on local institutional cultures and practices, as well as peer to peer relationships (Wolfram & Frantzeskaki, 2016). The primary drivers of change within this epistemology can be characterized as ecological, social, and cultural. These are complemented slightly by technological and demographic drivers of change (Wolfram & Frantzeskaki, 2016).

Table 1. Summary of socio-technical system epistemologies for urban experimentation (Wolfram & Frantzeskaki, 2016). Table created by author.

Epistemology	Focus	Primary Stakeholders	Socio-Technical System Focus	Primary Drivers of Change
1. Transforming Urban Mechanisms and Political Ecologies	Reduce the city's carbon and ecological footprint Support economic growth Uphold present living standards	Local Government Infrastructure Providers Technology Providers	Energy and material flows (e.g. energy, water, waste, transport)	Political Economic Ecological Technological
2. Configuring Urban Innovation Systems for Green Economies	"Green" production and consumption patterns by decreasing their resource intensity	Government Agencies Industry Subject Matter Experts Academic Institutions	Local innovation systems related to product and service production	Economic Ecological Technological
3. Empowering Urban Grassroots Niches and Social Innovation	Take ethical action to meet individual and group needs while remaining cognizant of environmental concerns Scaling up initiatives	Civil Society Actors	Food, education, health, renewable energy, etc.	Ecological Social Cultural

2.4 Transition Pathways

Four transition pathways are associated with the MLP (Geels et al., 2016; Geels & Schot, 2007). These ideal-type transition pathways delineate different ways in which the three analytical levels of the MLP - the regime, niche, and landscape - may interact and lead to transformation (Geels & Schot, 2007).

The different pathways are characterized by the timing and nature of these interactions (Geels & Schot, 2007). The interactions between actors, formal institutions, and technologies have also been identified for every pathway (Geels et al., 2016). A transition movement can also switch between pathways as it develops over time (Geels et al., 2016; Geels & Schot, 2007).

Central to defining and differentiating the four typologies is an understanding of the "timing and nature of interactions"(Geels & Schot, 2007). Geels & Schot (2007) explain that timing has to do with the alignment of landscape pressure with the maturity of niche innovations. For example, the landscape may pressure the regime in such a way that "windows of opportunity" open for the niche innovation to become more prominent within a socio-technical regime or take over a socio-technical regime. However, if niche innovations are not fully developed, they will not be able to take full advantage of this window to drive a transition forward. The nature of the interactions has to do with the type of relationship the landscape and niche have with the regime. These relationships can be either reinforcing or disruptive. Any interaction that strengthens the regime is reinforcing, whereas any interaction that exerts pressure on the regime is seen as disruptive. Similarly, niche innovations can have a competitive or symbiotic relationship with the regime. Competitive innovations compete with the established regime, whereas symbiotic innovations can be adopted into the regime to solve problems (Geels & Schot, 2007).

Bulkeley and Castán Broto (2013) assert that experiments have a governance aspect and that the MLP framework has fallen short when it comes to politicizing experimentation and considering the role of conflict and power relations. In response, Geels et al. (2016) further advances the typology with a local conceptual logic in which the smaller, short-term action taken throughout an innovation's development is brought into focus. More specifically, the expected interactions between actors, institutions, and technologies are explicitly presented for each typology to illuminate how the struggles between actors can drive specific transition pathways and pathway shifts (Geels et al., 2016). It is this local context that allows for a richer application of the MLP framework and determination of the transition pathway in my case study.

Each of the following four sections expound on a single transition pathway. These pathways include transformation, de-alignment and re-alignment, technological substitution, and reconfiguration. A summary of these pathways is provided in Table 2.

2.4.1 Transformation

If the landscape exerts pressure on the regime, but niche innovations are not mature, then regime actors will have the opportunity to modify "the direction of development paths and innovation activities" (Geels & Schot, 2007, p. 407). In this case, landscape pressure is disruptive, and niche-innovations are symbiotic. Eventually, after many adjustments, a new regime will develop out of the old one, although regime actors will remain constant (Geels & Schot, 2007). That is not to say that incumbent actors resist change or are "locked in" to the dominant regime patterns. They do have the capacity to re-orient themselves decisively in a new direction (Geels et al., 2016). The degree of reorientation determines the amount of institutional change that occurs. If reorientation efforts are strong and new technologies are adopted quickly than a higher degree of institutional change may take place (Geels et al., 2016). Otherwise, a lack of reorientation efforts is associated with the incremental nature of technical niche-innovation adoption into the regime and this leads to limited institutional change (Geels et al., 2016). It is possible that institutional pressure evokes struggles between policy makers and industry actors (Geels et al., 2016).

2.4.2 De-alignment and Re-alignment

If the landscape pressure is large and sudden then significant pressure will be placed on the regime (Geels & Schot, 2007). If this causes regime tensions to escalate to a point where incumbent actors begin to lose faith, then the regime will begin to break down, which results in de-alignment (Geels & Schot, 2007). If during this time niche-innovations have failed to reach maturity, then there will be an emergence of and competition between multiple niche innovations (Geels & Schot, 2007). Eventually, one niche-innovation will become dominant and a new regime will re-align around it (Geels & Schot, 2007). Within this pathway, there is no direct confrontation between incumbent and new actors (Geels et al., 2016). By extension, there is no real competition between the niche-innovations and the 'old' technology. This is because the "old" technology loses its dominance with the de-alignment of the regime (Geels et al., 2016). Eventually de-aligned institutions are replaced, but there could be a long period of uncertainty while these new institutions are built up (Geels et al., 2016).

2.4.3 Technological Substitution

If the landscape pressure is large and niche-innovations are mature then the niche-innovation will become dominant and thus induce a regime shift (Geels & Schot, 2007). However, in this case, the regime is not completely destabilized before the niche-innovation attempts to replace the old technology. Thus, there is competition between incumbent and new actors (Geels & Schot, 2007). Niche innovations may be pushed to compete with the old technology by both "outsiders," such as activists, social movements, and citizens, or by incumbents who have switched sectors (Geels et al., 2016). Within this pathway, institutions can either experience limited change or disruptive change. Limited institutional change is the norm when the developed niche-innovations fit into existing rules and institutions, and disruptive change occurs when they do not and institutions are forced to adjust (Geels et al., 2016). These institutional struggles will likely incite power struggles (Geels et al., 2016).

2.4.4 Reconfiguration

When niche innovations are symbiotic, the regime will adopt them in order to solve local problems. Eventually, innovation adoption may create tension within the regime that opens up opportunities for an increasing number of niche-innovations to be adopted, which causes "adjustments in the basic architecture of the regime" (Geels & Schot, 2007, p. 411). Knock-on effects, which refer to new combinations between innovations, may also prompt structural changes within the regime (Geels et al., 2016). Generally, these adoptions are motivated by economic reasons, improved performance for example (Geels & Schot, 2007). Although the incumbent actors are not removed in this transition pathway, competition and tension is still evident (Geels & Schot, 2007), as new alliances may be formed with new actors (Geels et al., 2016). Institutional change is limited at the start of this process, but eventually substantial change occurs (Geels et al., 2016).

Table 2. Summary of transition pathways (Geels et al., 2016; Geels & Schot, 2007). Table adapted and created by author.

TRANSITION PATHWAY	NATURE OF LANDSCAPE	NICHE-INNOVATION MATURITY	NATURE OF NICHE-INNOVATION	OUTCOME	ACTORS
Transformation	Disruptive	Not Mature	Symbiotic	Regime actors modify the development path of the regime and adopt niche-innovations The degree of reorientation determines the degree of institutional change Eventually, a new regime emerges out of the old one, but the basic regime structure does not change	Regime actors are not replaced Policy makers and industry actors struggle with each other
De-alignment and Re-alignment	Disruptive	Not Mature	Competitive	Landscape pressure causes regime tensions to increase The regime breaks down Niche-innovations compete to replace the regime One niche-innovation becomes dominant	Regime actors are replaced No direct confrontation between incumbent and new actors occurs
Technological Substitution	Disruptive	Mature	Competitive	The niche-innovation replaces the regime and a regime shift occurs The degree of institutional change depends on whether the niche-innovation aligns with existing rules and institutions	Regime actors are replaced Competition between incumbent and new actors occurs
Reconfiguration	Disruptive	Not Mature	Symbiotic	Adoption of niche-innovations by the regime alters the structure of the regime New combinations of niche-innovations create knock-on effects Institutional change grows over time	Regime actors are not replaced Competition among regime actors exists and new alliances may be formed with new actors

3 Method

The proposed research questions were investigated via case study, which is an established qualitative approach where a real-life, bounded system is explored over time using multiple sources of information to provide a case description and identify case themes (Creswell & Poth, 2018). Furthermore, the case analysis was theoretically informed.

3.1 Theoretical Development

This thesis' theoretical foundations are rooted in sustainability transition studies. This field was initially explored through a literature review, which revealed the divide between socio-technical (STS) and socio-ecological systems (SES), of which STS were chosen for further exploration. A dominant theoretical framework within this ontology is the multi-level perspective (MLP), which was explored extensively through a second literature review. The first literature review included searches in Google Scholar using the term "sustainability transition studies" and snowballing from the reference lists of those articles. The second literature review consisted most prominently of Geels' and Geels and Schot's primary works on the subject matter. Most importantly, the review of the MLP literature provided an introduction to transition pathways, which outline the different ways in which a transition may occur, based on the characterization of interactions between the analytical levels of the MLP (Geels et al., 2016; Geels & Schot, 2007). The MLP in conjunction with the transition pathways provided the theoretical basis for answering the second research question.

The initial review of sustainability transitions literature also revealed the existence of research centered around urban experimentation. A third literature review of this material was conducted through keyword searches in Google and Google Scholar and snowballing from relevant articles. Keywords included combinations of "urban experiment," "sustainability transitions," and "Sweden." This search not only revealed literature specifying how to classify urban experiments, but also literature describing how to categorize research within four epistemologies, of which three were relevant to STS. This literature review in conjunction with the one concerning the MLP provided the theoretical basis for answering the first research question. These connections are depicted in Figure 3.

3.2 Case Boundaries

Brunnshög was chosen as the case study because, as outlined in section 2.3.1, it is a prime example of urban experimentation in Sweden. Not to mention, there are a large number of innovations planned for the area, which provides for an interesting and worthwhile MLP analysis. Importantly, this case is bounded by space and time. Brunnshög is a developing district whose planning phase was initiated in 2010 and whose development is ongoing (Lund Municipality, 2012a, 2019). As such, the overlapping planning, development, and living phases between 2010 and the present, were included within the bounds of this case study. Additionally, only innovations planned to take place within the area of Brunnshög and the tram line running through the city of Lund, whose construction was motivated by Brunnshög's development (Lund Municipality, 2019), were considered as part of the study. More specifically, this case study can be classified as instrumental since the main interest lies within the insights Brunnshög may provide with regards to the importance of urban experimentation for sustainability transitions in Sweden.

3.3 Data Collection and Analysis

Since data collection for case studies requires that two or more sources of information are used (Creswell & Poth, 2018), I chose to review relevant documents, as well as conduct semi-structured interviews. Since Brunnshög is still at the start of the development phase, I chose to review all the documents outlining the vision of Brunnshög. Interviewing was chosen as the second source of information since speaking with people involved in the project, who have extensive knowledge about the entire planning and development process, could reveal details or nuances not captured in public documents. In this way, the document review and interviews should provide complementary information. The documents reviewed were primarily sourced from Lund Municipality's website for Brunnshög. I reviewed all material available on the website and chose the documents that were most relevant to developing an in-depth case description and answering my research questions. In this way, I ensured that the majority of reviewed documents were primary sources. The few documents sourced outside the municipality's website were recommended or provided by members of the municipality. In the end, two key-informant interviews were carried out. One interview was not recorded, although extensive notes were taken, while the other was recorded and transcribed. The interviews lasted between 30 minutes and an hour.

While many innovations for Brunnshög were proposed, I identified niche-innovations as those that were presented as special to Brunnshög. I then classified these innovations according to the STS to which they were most relevant. Of the five STS identified, the four most prominent were selected as the case themes. These themes then became the focus of the document review I performed to explore current, dominant regimes. In this instance, I reviewed material from government websites, legal documents and reports, and searched for literature through Google and Google Scholar using each regime name paired with a location (e.g. transport system in Lund). I used the knowledge I gained while researching Brunnshög and the regimes to identify relevant proponents of the landscape and then performed Google and Google Scholar searches to find specific information supporting those topics.

Identifying aspects of the niche, regimes, and landscape, as they relate to the case study of Brunnshög and the case themes, allowed for the application of the MLP framework to address my research questions. An analysis of regime-niche and landscape-regime interactions helped me identify Lund's current transition pathway and Brunnshög's role in upholding it. This directly addressed my second research question. The first research question is partially answered by the identification and classification of regime-niche interactions. In order to finish answering the first research question, I used the urban experiment epistemologies to identify the approach to urban experimentation that is being taken in Brunnshög. While the discussion surrounding regime-niche interactions provided a nuanced look at how specific innovations targeted established STS, this classification provided insight into Brunnshög's general approach to innovation and change. This analytical process is depicted in Figure 3, as are the relationships between my theoretical and analytical processes.

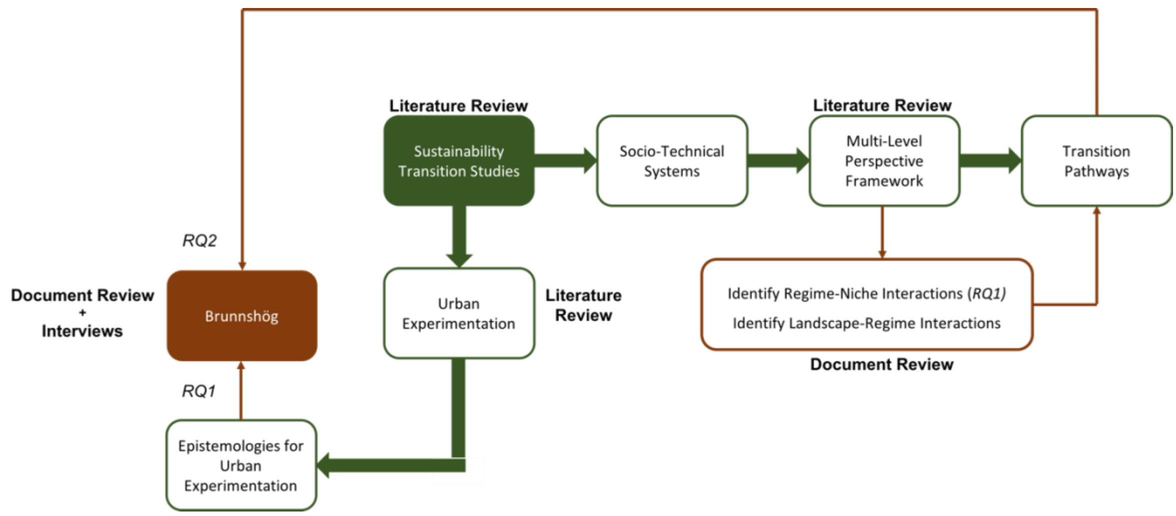

Figure 3. Theoretical and analytical process (own illustration). Theoretical relationships are represented by the green boxes and arrows, while the analytical process is represented by the brown boxes and arrows. RQ1 and RQ2 indicate the analytical processes used to answer research questions 1 and 2 respectively. Bolded text indicates the data collection method used to gain the specified information.

3.4 Limitations

There are two major limitations to this research design. First, although the start of this case can be traced back to the early 90s, it is still ongoing today. In fact, Brunnshög's development is expected to continue for another 35-40 years. This is a limitation in the study, since conclusions about Brunnshög's greater impact are largely drawn from visioning documents about future development plans. Thus, any conclusions drawn with regards to this represent the intent and potential of the project, rather than decisive deductions. Second, given current events, the acquisition of interviews was difficult. However, the interviews that could be obtained were immensely helpful in identifying development dynamics not portrayed in official reports and great suggestions were made for further research. It would have strengthened the analysis though if more interviews could have been conducted.

4 The Case of Brunnshög

Brunnshög is a new district of Lund being developed in the North-East (Lund Municipality, 2012a). Lund municipality has guided Brunnshög's development since the area was first conceptualized in the late 1990s (Lund Municipality, 2012a). It was not until 2006, however, that the first framework for the area was developed (Lund Municipality, 2012a). This framework was further revised in 2010 and the first document depicting how the framework could be actualized was published in 2012 (Lund Municipality, 2012a). This document (revised further in both 2016 (Lund Municipality, 2016c) and 2019 (Lund Municipality, 2019)) provides an in depth, publicly accessible vision for the area's development and its overarching goals (Lund Municipality, 2012a). Namely, that Brunnshög aims to develop the world's best research, innovation, and living environment where new solutions for sustainability are sought (Lund Municipality, 2012a). Furthermore, Brunnshög aims to be a leader in sustainability (Lund Municipality, 2019) and sustainable development (Lund Municipality, 2012a). In other words, a European best practice example that demonstrates how to take responsibility locally for the global challenge that is climate change (Lund Municipality, 2019).

4.1 Physical Layout

Brunnshög's development was partially motivated by the planned construction of two research facilities, the European Spallation Source (ESS) and MAX IV (personal communication, February 28, 2020), which are expected to create one of the world's leading centers for materials research; an area that attracts nearly 8,000 visiting researchers annually (Lund Municipality, 2012a). Those working in these facilities will need places to gather and live, so Science Village will be constructed in the area between them (Lund Municipality, 2012a). However, these facilities are located slightly outside of the urban area of the city and this provides an expansion opportunity (personal communication, February 28, 2020). As seen in Figure 4, the area connecting the built city with these research facilities will consist of Södra Brunnshög [Southern Brunnshög], Västra Brunnshög [Western Brunnshög], Centrala Brunnshög [Central Brunnshög], and Rååangen. Other development areas of note include Bygatorna [Village Streets] and Kunskapsparken [Knowledge Park]. Additionally, a tram line will run from Lund's train station to ESS, connecting Brunnshög to the rest of the city (Lund Municipality, 2019). MAX IV opened in 2016 and ESS is under construction with an opening planned for 2023 (*MAX IV and ESS*, 2020). Meanwhile, construction of Södra Brunnshög began in 2015 (Lund Municipality, 2016c) and the first resident building was completed and populated in this area in 2019 (Lund Municipality, 2019). Construction in this area is ongoing and the construction of the entire district is expected to take 40 years to complete (Lund Municipality, 2016c). This longer time period necessitates a continuously evolving and iterative planning process (Lund Municipality, 2012a).

Figure 4. Map of Brunnshög's development areas (Lund Municipality, 2019).

4.2 Planning Process and Primary Stakeholders

A 2014 amendment to the Planning and Building Act prevents municipalities from making specific demands of their development partners regarding technical standards (*Planning and Building Act*, 2018; personal communication, March 31, 2020). Thus, the municipality has adapted a unique contractor recruitment strategy to ensure that overall sustainability goals are still being met. Now, the municipality proposes the overall sustainability goal, such as having designated areas for more urban food production, and the contractors develop their own methods for meeting that challenge (personal communication, March 31, 2020). In the end, the municipality gives the project to the contractor who they believe has developed the most interesting solution and a sustainability agreement is reached (personal communication, March 31, 2020). This agreement is a needed tool for dialog in the absence of top-down directives and naturally places an emphasis on collaboration (personal communication, March 31, 2020). In this way, the developers have the freedom to create their own, innovative solutions to sustainability challenges and the municipality hires developers who have greater motivation, since they are acting on behalf of themselves and their innovations (personal communication, March 31, 2020). The importance of collaboration in the development process is also emphasized in the original visioning document (Lund Municipality, 2012a), which indicates that it was held as an ideal even before the current recruitment strategy was enforced by law.

Primary stakeholders include Lund municipality, Kraftringen (energy company), VA Syd (water management company), and the municipality’s Department of Waste Management (personal communication, March 31, 2020). Additionally, Lund University and Region Skåne own stakes in the development of Science Village, Max IV is a Lund University facility, and ESS is a European facility whose development has been dependent on researchers and engineers from all over the world (personal communication, February 28, 2020). MAX IV, ESS, and Science Village are independent projects to a certain extent and are becoming more autonomous from Lund Municipality as time goes on (personal communication, February 28, 2020). Notably, there was little community input throughout the planning process (personal communication, February 28, 2020). The municipality does hope to increase citizen participation though since people are now moving into the area (personal communication, February 28, 2020). Future development areas are yet to be fully designed (Lund Municipality, 2016c), which provides an opportunity for community members to become more involved in Brunnshög’s ongoing development. Indeed, the original visioning document does indicate that this involvement is desired (Lund Municipality, 2012a).

4.3 Sustainability Orientation

The Brunnshög project is oriented towards sustainability because the vision for the area and its continued development has occurred in a time when sustainability is acquiring more and more awareness (personal communication, February 28, 2020, March 31, 2020). During this time, it has become increasingly clear that action must be taken to lessen global warming (IPCC, 2014, 2018).

Therefore, throughout the project, there has been political unity within the city of Lund that new city development should be as sustainable as possible (personal communication, March 31, 2020).

This has led to the development of three primary sustainability principles that all sustainable development in Brunnshög is centered around (Lund Municipality, 2018): (1) minimize climate impact, (2) balance the use of quality agricultural land, and (3) maximize experiences, sensory and otherwise, and meeting places (Lund Municipality, 2012a, 2016c, 2019; personal communication, February 28, 2020). These principles are associated with economic, ecological, and social & cultural sustainability respectively (Lund Municipality, 2012a, 2016c, 2019).

4.4 The Importance of Economic Growth

A desire for economic growth exists alongside this focus on ecological, economic, and social sustainability. The economic component of sustainability addressed within the project does not attempt to limit growth, but rather centers around minimizing the climate impact associated with everyday living. In other words, increasing the efficiency of systems and decreasing use of fuels that emit GHG (Lund Municipality, 2018).

The development of Science Village is a clear example of Brunnshög's aim to increase growth. Science Village is envisioned as a business base that integrates different people and experiences (Lund Municipality, 2012a). This area will provide space for business and research to come together in order to promote innovation and the development of new companies that are capable of translating research into new products and services (Lund Municipality, 2012a). Additionally, Lund Municipality (2012a) has stated that the tram needs to be attractive to businesses. These businesses, as well as other services and dense buildings will surround tram stops in order to encourage people to exit (Lund Municipality, 2012a). Lastly, Brunnshög is intended to act as a tourist destination, where people are attracted by restaurants, culture, science, and recreation (Lund Municipality, 2019). These initiatives will draw people and business into the area, which is sure to contribute to economic growth.

4.5 Community and Innovation

Ideas centered around increasing a sense of community and providing experiences are central to Brunnshög's plan for social sustainability. The developers of Brunnshög aim to create a space where the environment itself is filled with experiences that stimulate the senses (Lund Municipality, 2012a). These experiences are thought to increase individuals' ability to thrive, and to be curious and spontaneous, as well as stimulate a good quality of life (Lund Municipality, 2012a). Meeting places are also planned to promote human interaction (Lund Municipality, 2018). Importantly, these meeting places could be as mundane as trash collection sites (personal communication, February 28, 2020) or as exciting as recycling rooms that double as a repair workshop, boutique, and café (Lund Municipality, 2018). The provision of experiences, meeting places, and ultimately a good living quality are expected to inspire creativity and innovation (Lund Municipality, 2018). Therefore, innovators will also be given space to test and share their ideas (Lund Municipality, 2018). These innovations are expected to target city challenges since Brunnshög will be a place where the conditions for living a sustainable lifestyle are created (Lund Municipality, 2018).

4.6 Niche-Innovations

The multi-level perspective framework broadly classifies niche-innovations as innovations that differ greatly from those which exist within dominant regimes. Therefore, while reviewing these documents, I pinpointed ideas and technologies that were presented as special to Brunnshög (Lund Municipality, 2012a, 2016c, 2018, 2019). Then I determined which socio-technical systems (STS) were most closely associated with these technologies and ideas, or niche-innovations. The identified niche-innovations, as well as their associated STS are presented in Table 3.

Table 3. Brunnshög's niche-innovations and associated socio-technical systems. The attribution of the innovations to specific socio-technical systems in column one was my own determination. The information presented in column two was gathered and synthesized from Lund Municipality reports (Lund Municipality, 2012a, 2016c, 2018, 2019) and an interview (personal communication, March 31, 2020). Since Brunnshög is still developing, some of these innovations are still visionary. Table created by author.

Socio-Technical System	Niche-Innovation
Transport	Two-thirds of traffic in and out of Brunnshög will consist of public transport, walking, and biking. The last third may be made up of cars.
	Pedestrians and cyclists are prioritized over cars in the district's street design. A car-free inner core will be promoted.
	Offer collective car parking solutions in order to increase carpooling and provide competitive advantages to other means of transport.
	Offer charging stations for electric cars in carparks.
	A new tram will connect Lund Central to ESS.
Energy & Heat	Energy sourced for Brunnshög is ideally local and climate neutral.
	Excess heat from MAX IV and ESS will be recycled for use in Brunnshög's buildings through both a normal and low temperature district heating system. This system will be the largest low temperature district heating network in the world.
	The buildings in Brunnshög will produce their own solar electricity.
	A smart grid may be used to control electricity production and consumption.
Waste Management	Vacuum collection systems will transport waste directly to the waste center (i.e. collection vehicles will not be needed).
	The repair of items should be prioritized over recycling them.
	A circular and sharing economy is encouraged over a linear economy.
	At least 50 percent of food waste will be recycled as such.
Food Production	Combine the qualities of urban and rural living by providing opportunities for residents to have urban farms in courtyards and on roofs and balconies.
	Facilitate plant growth in courtyards by minimizing sealed surface areas.
	30 percent of the land used to build upon must be capable of being restored to arable land in the future.
Water Management	Integrate some stormwater management into city spaces in order to minimize flooding, maintain stormwater quality, and control the negative effects of rainy weather.

I will discuss these innovations further in sections 5.3 and 5.4 in relation to the landscape and relevant regimes. This analysis will focus on the four most prevalent STS: transportation, energy and heating, waste management, and food production.

5 Landscape, Regimes, and Niche-Innovations

In this thesis, I designate the city of Lund itself as the socio-technical regime, Brunnshög as the niche, and innovations within Brunnshög as niche-innovations. Relating the district of Brunnshög and the city of Lund to the multi-level perspective (MLP) framework in this way localizes the multi-level analysis. Doing so bounds the regime and niche analysis to technology, politics, economics, and culture present at the local level. However, I acknowledge that the socio-technical landscape is nationally and internationally constructed to a certain extent, so identifying Sweden's political ideology and macro-economic patterns, as well as global influences, will be necessary.

The first two sections of this chapter present justified descriptions of the landscape and regimes. The final two sections present an analysis of interlevel interactions based on the information provided in previous sections and the MLP framework.

5.1 Landscape

The landscape categorizes influences that are outside the realm within which the regime and niche have direct, short-term power (Geels, 2011). This may include, for example, political ideologies, macro-economic patterns (Geels, 2011), public awareness, and government commitments (Fischer & Newig, 2016). With regards to the Brunnshög case, there are three relevant landscape components: (1) Swedish urban planning is decentralized, (2) Swedish policy concerning sustainability and sustainable urban development is characterized by eco-modernity, and (3) global awareness of both climate change and the necessity of radical action is growing.

Sweden's government is characterized as a parliamentary democracy and consists of three different levels – the national, regional and local (*How Sweden Is Governed*, 2020). Importantly, the local and regional levels are responsible for different tasks, and as a result, are not hierarchical (*Municipalities and Regions*, n.d.). The local level is made up of 290 municipalities (*How Sweden Is Governed*, 2020) and it is to this authority that Sweden's national government has awarded the responsibility for urban planning (*Planning Process*, 2018). Along with the Planning and Building Act and Environmental Code, national objectives are provided by the State to guide development, but the municipalities are largely free to determine how these overall objectives are met (Madureira, 2014; *Planning Process*, 2018). Thus, urban planning has been decentralized within Sweden and this naturally impacts urban planning practices.

In 1987, the World Commission on Environment and Development (WCED) published a report entitled "Our Common Future," which is commonly recognized as the Brundtland Report today. In this report sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 37), which requires that social equity and ecological factors are considered when making economic decisions (WCED, 1987). Sweden's Environmental Code defines the country's conceptualization of sustainable development, which is in line with the Brundtland report (Miljöbalk, 1999). Sustainable development was first established as a national goal in 1998 (Hilding-Rydevik et al., 2011; Svenska miljömål, 1998). This focus on sustainable development has continued to expand over the last 20 years. In 2015, Sweden announced that it aimed to be one of the first fossil-free nations (Ministry of the Environment and Energy, 2015). The introduction of the Swedish climate policy framework followed in 2017 (Ministry of the Environment and Energy, 2018a). This framework details how the Paris Agreement will be implemented within the country, and the associated climate act took affect January 1, 2018 (Ministry of the Environment and Energy, 2018a). Most recently, in 2018, Sweden's first national strategy for urban development was published (Ministry of the Environment and Energy, 2018b). Given the country's alignment with the Brundtland report, it is unsurprising that action taken throughout this time can be characterized as eco-modern, which is defined by Midttun and Olsson (2018) in the Nordic context as "the coupling of ecological sustainability to industrial development and welfare creation in order for a country to benefit from its resources and capabilities, while also furthering green growth" (p. 215). Given that sustainability and sustainable development have been increasingly present in policy and action over the past 20 years, I argue that it has become a part of Sweden's political ideology.

Finally, ratification of the 2015 Paris Agreement, recent IPCC reports, and the ongoing youth movement have greatly increased awareness of climate change, and awareness that actions being taken today will not be enough to limit climate change to 1.5°C. The Paris Agreement commits countries to take action that would prevent the global temperature from rising 2°C above pre-industrial levels (United Nations Framework Convention on Climate Change [UNFCCC], n.d.). This agreement is attempting to coordinate a global response to climate change that is unprecedented (UNFCC, n.d.). As of 2020, 187 countries have ratified the agreement (Apparicio & Sauer, 2020). In the fall of 2018, the IPCC released a special report about global warming of 1.5°C above pre-industrial levels which underscored the necessity of "rapid, far-reaching and unprecedented changes in all aspects of society" if global warming is to be effectively mitigated (IPCC Secretariat, 2018, p. 1).

Furthermore, Greta Thunberg, a Swedish activist, references this IPCC report in her speech to the National Assembly in Paris in the summer of 2019 where she asks leaders to listen to and unite behind the science with regards to action for climate change (FridaysForFuture, 2019). Greta is just one of many child activists around the world (Parker, 2020). However, she sparked the international Fridays for Future movement, in which children skip school on Fridays to strike for the climate (Haynes, 2019). On March 15, 2019, it is estimated that 1.6 million people in 133 countries were striking for the climate (Haynes, 2019). Young people around the world have joined a movement that is continually pressuring national governments to take the steps needed to successfully address global warming and climate change.

5.2 Regimes

As described in section 2.2., socio-technical systems (STS) are defined by a dominant regime that consists of six sub-regimes that, when aligned, can reinforce the dominant regime, causing STS lock-in (Geels, 2004). In order to address the first research question, a comparison must be made between the STS' associated regimes and sub-regimes and the niche-innovations within Brunnshög. Therefore, only the regimes of the STS within Lund that are most relevant to the case study of Brunnshög will be summarized. These include the transportation, energy and heating, waste management, and food production systems. Developing a clear understanding of these regimes is also central to answering the second research question, since classifying the interactions between the niche-innovations, regimes, and landscape allows for the identification of the current transition pathway in Lund.

5.2.1 Transport

A long-term, sustainable transport system is a central policy objective of Sweden's national government (Stjernborg & Mattisson, 2016). However, by law, regional administrative authorities manage regional public transport (Stjernborg & Mattisson, 2016). This results in some differentiation across the country with regards to what transport systems truly attempt to achieve (Stjernborg & Mattisson, 2016). In their report envisioning transport infrastructure development from 2018 to 2029, Region Skåne (n.d.) names system efficiency, accessibility, and environmental friendliness as priorities alongside increasing investment into public transport options and cycling. Current transport options within Skåne, and Lund specifically, include walking, bicycling, and traveling by train, bus, and car (Region Skåne, n.d.). Lund Municipality (2012b) relayed in their traffic strategy for Brunnshög, that between 55 and 60 percent of traffic in the area was made up of cars.

Important actors in this sector include Region Skåne, Skånetrafiken, and Lund Municipality. Region Skåne has the final word on decisions concerning public transport in Skåne (*Our Responsibilities*, 2018). Region Skåne carries out its work through the Skånetrafiken administration (*Our Commission in Public Transport*, 2018), who communicates with municipalities in turn (Region Skåne, 2018).

5.2.2 Energy and Heating

Energy sources primarily support electricity, heat, and fuel generation (Swedish Energy Agency, 2019). These are then predominately used within the transport, residential and service, and industry sectors (Swedish Energy Agency, 2019). As of 2017, electricity is mainly used in the residential and service sector, the industrial sector is most heavily dependent on biofuels, and the transport sector derives 75 percent of its energy use from petroleum products (Swedish Energy Agency, 2019). Swedish energy goals mandate that energy efficiency should increase 20 percent between 2008 and 2020 and that renewable energy should make up a minimum of 50 percent of total energy use by 2020 (Swedish Energy Agency, 2019). These goals make clear that, within this sector, sustainability is synonymous with renewable energy use.

The heating market is the second largest energy market in the country (Swedish Energy Agency, 2019) and is predominately made up of district heating, electric heating, heat pumps, and biofuel boilers (Sköldberg & Rydén, 2014). Of the four, district heating is the most used technology (Sköldberg & Rydén, 2014). The heating market is efficient in terms of both energy and resource use. In this way, it is already considered to be very environmentally sustainable and is a main contributor to Sweden's sustainable development goals (Sköldberg & Rydén, 2014). Indeed, fossil fuel use within the heating market has decreased by 90 percent over the last 20 years (Sköldberg & Rydén, 2014).

Kraftringen is an energy company owned by four municipalities, including Lund (*Kraftringen*, 2019). This company handles a share of electricity distribution, as well as district heating and cooling in Lund and their district heating system has run on renewable energy since 2018 (*Kraftringen*, 2019).

5.2.3 Waste Management

According to Sweden's environmental code, waste management includes the collection, transport, recycling, and disposal of waste (Miljöbalk, 1999). Municipalities determine how waste management will be carried out (Avfall Sverige, 2019). Typically, management practices prioritize an overall reduction in waste production, followed by reuse, recycling, energy recovery, and landfilling (Avfall Sverige, 2019). In Lund, the municipality's department of waste management is responsible for the collection of waste (2016b), although everyone, including individuals, households and companies, must take care of their waste in ways that preserve human health and the environment, which includes sorting and recycling (Lund Municipality, 2016a). Furthermore, Lund Municipality (2016b) released a visioning document that defines three focuses of sustainability: (1) consuming sustainably in order to reduce waste, (2) sorting waste sustainably in order to increase recycling, and (3) handling waste in ways that promote a clean environment. Sustainability is not only central to transport and energy system development, but to the waste system as well.

5.2.4 Food Production

About half of the land available in Skåne is agricultural and contributes 16 percent of the total agricultural land in the country (Statistics Sweden, 2013). As of 2015, about 55 percent of the land in Lund Municipality was agricultural and just over ten percent was developed (Statistics Sweden, 2015a). As urban areas expand though, this agricultural land becomes threatened, since developed land typically cannot be reconverted to arable land (Hallgren, 2015). Within Sweden and Lund, there is a clear demarcation between the function of urban and rural areas, so agricultural land is solely responsible for commercial food production within the country (Statistics Sweden, 2015a). Sweden does not have the capacity to support current consumption levels though (Hallgren, 2015), so a large percentage of food must be imported.

On the other hand, there is a tradition of urban cultivation where those living in the city have the opportunity to rent out a limited number of allotment gardens where they may grow fruits and vegetables for personal consumption (*Cultivation plots and urban gardening*, 2019). Lund also provides these plots, whose allocation is controlled by the municipality (*Cultivation plots and urban gardening*, 2019). As of 2015, Skåne offered the largest number of plots of any county at 576, of which 48 were available in Lund Municipality (Statistics Sweden, 2015b).

According to the Swedish Board of Agriculture, the national government has published a food strategy to guide national policy related to food production through 2030 (Jordbruksverket, 2018). This strategy emphasizes the importance of establishing both a sustainable and competitive food supply chain (Jordbruksverket, 2018).

5.2.5 Socio-Technical System Interconnectivity

As shown in Figure 5, these STS are interconnected. Food waste can be collected and processed to produce either bio-fertilizer or biogas (Lunds Renhållningsverk, n.d.). The biofertilizer can be used on agricultural fields to aid in further food production, whereas biofuel can be used as an energy source (Lunds Renhållningsverk, n.d.). Biofuel can be processed into a liquid fuel for vehicles or it can be used to produce heat and electricity that supports district and electric heating systems (Avfall Sverige, 2019; Lunds Renhållningsverk, n.d.). As of 2012, Lund Municipality ran all city buses and 50 percent of waste collection vehicles on biogas (Lunds Renhållningsverk, n.d.). Additionally, general waste incineration can also support heat and electricity production (Avfall Sverige, 2019). Within Sweden, energy recovery via waste incineration supplies 680,000 households with electricity and 1.2 million households with district heating (Avfall Sverige, 2019). Figure 5 demonstrates that STS within urban areas are interconnected and that action taken within a single system can have ripple effects across many others.

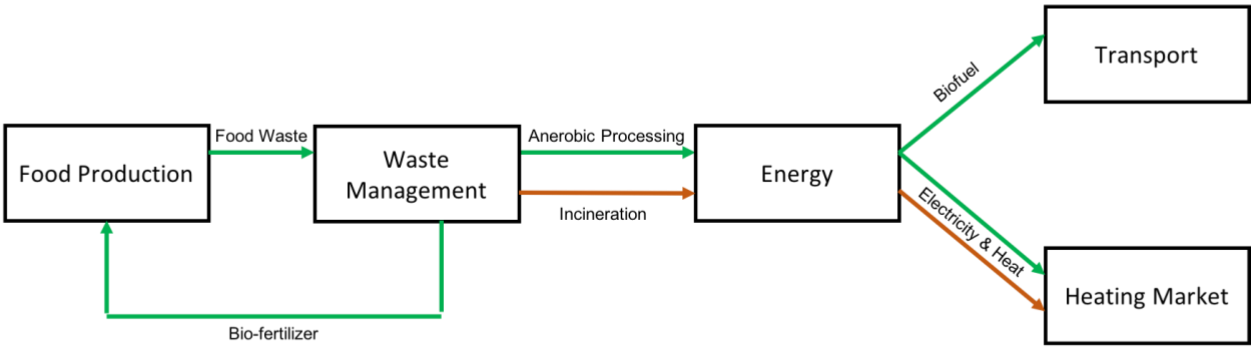

Figure 5. Interconnectivity of socio-technical systems (own illustration).

5.3 Regime-Niche Interactions

Lund Municipality is an incumbent regime actor that has initiated and steered the development of Brunnshög from the beginning. Thus, the development of most niche-innovations are being guided by stakeholders who also hold power within the current regimes, such as Kraftringen, the municipality's Department of Waste Management, Lund University, and Region Skåne, among others. The major opportunity for actors outside the regime to make an impact is through a development contract for an area of Brunnshög or through citizen participation. However, the companies chosen for these development projects must be approved by Lund Municipality, and the municipality has just begun interacting with the community.

National, and therefore municipal, sustainability goals center around reducing GHG emissions (Midttun & Olsson, 2018). Given that the transport sector derives 75 percent of its energy from petroleum products (Swedish Energy Agency, 2019) and accounts for 32 percent of national GHG emissions (Swedish Environmental Protection Agency, 2018), it is being heavily targeted in Brunnshög. In order to limit these emissions, developers have set a goal for Brunnshög requiring that two-thirds of transport needs in and out of Brunnshög must eventually be met by public transport, walking and biking. This niche-idea is directly competing with the transport regime. Action to make this a reality includes prioritizing pedestrians and bikers when designing the streets so that the inner areas of the district remain car-free. Additionally, collective car parking solutions and carpooling services will be offered. Finally, in order to support the transportation needs of this new district, the first tram line in Lund is being constructed. The tram is considered to be space efficient, quiet, and run on green electricity (Lund Municipality, 2017). By making it harder to park, limiting the areas where cars are allowed to drive, and providing an additional public transport option, the developers of Brunnshög are incentivizing car-free travel and undermining the most common transport method. The tram's development is being managed by Skånetrafiken and Lund Municipality. These actions are not being taken to the detriment of economic growth, however. The municipality intends for public transport to "ensure the future of retailers and businesses," whilst allowing for city expansion (Lund Municipality, 2017, p. 2). The tramline in particular is considered "a regional investment in the future" with regards to sustainability and growth, as it "will be the driving force of development along its route," with 30 percent of Lund's expansion through 2050 planned along its path (Lund Municipality, 2017, p. 2). Action being taken within the transport sector is a clear example of eco-modernization.

Energy industries are responsible for 17 percent of national GHG emissions (Swedish Environmental Protection Agency, 2018). Nearly three quarters of this can be attributed to the heating market (Swedish Environmental Protection Agency, 2018). Though it is substantially more sustainable than the transport sector, lowering heating emissions is still necessary. Brunnshög is able to do this through the adoption of a low temperature district heating (LTDH) system. Brunnshög is uniquely positioned to take advantage of excess heat being produced by the two large research facilities, ESS and MAX IV. Reusing this heat within a LTDH system will contribute to Brunnshög's vision for sourcing local and climate neutral energy. LTDH systems also have better efficiency than standard district heating systems (Schmidt et al., 2017) and are a developing technology (Werner, 2017). Kraftringen will attempt to construct the largest LTDH system in the world within Brunnshög. Given that district heating has been used within Sweden since 1948 and comprised 55 percent of the heating market in 2014 (Werner, 2017), this technology is symbiotic with the current regime and can be incorporated to further improve the existing system.

Plans for the waste management system also support transport goals. If streets are to be designed for pedestrians and cyclists, and cars are to be kept out of many areas within the district, then there will be no room for large waste collection vehicles to maneuver. Therefore, the Department of Waste Management has decided to incorporate a vacuum waste system into Brunnshög's development from the start. According to the 2018 report on Sweden's waste management system, the implementation of vacuum waste systems is increasing throughout cities and within newly built areas (Avfall Sverige, 2019). This innovation, while not brand new, is central to facilitating Brunnshög's pedestrian-centric design aspirations. Its adoption into the current system is already underway, which indicates a symbiotic relationship with the waste management regime. However, its application strives to support a truly niche urban design concept within the transport sector. Therefore, I have determined that this innovation supports other niche-innovations' competition with the transport regime.

Consistent with this regime's current stance policy-wise, reusing and repairing items will be prioritized over recycling of those same items within Brunnshög. This feeds directly into Brunnshög's aim to encourage a circular or sharing economy. Spaces needed to repair and exchange items will be created throughout Brunnshög. These spaces will double as meeting places and also serve to promote a stronger sense of community within the district, which also challenges current cultural norms (personal communication, February 28, 2020). Lastly, biogas production from food waste currently fuels all city busses in the city of Lund. Brunnshög aims for 50 percent of food waste to be recycled as such within Brunnshög, which would support this more established innovation. This action is not innovative within itself, but instead serves to preserve and strengthen an innovation that has been adopted within Lund and will continue to be utilized in Brunnshög.

Space for urban gardening within parks, courtyards, balconies, and atop roofs will be provided in Brunnshög and is disruptive to the food production regime's separation of rural and urban land as land for food production and land for residence and businesses respectively. This separation is currently culturally and infrastructurally enforced. Providing space for urban gardening throughout the district challenges this though by making gardening central to daily life. Additionally, building in a way that allows for the possibility of future restoration of arable land is directly counter to typical design plans and may be vital to food production in the future.

5.4 Landscape-Regime Interactions

Rising global awareness of climate change has resulted in social movements, like Fridays for Future, that put pressure on national governments to take action which mitigates global warming. This pressure is exerted across all STS regimes. In the Brunnshög project, the landscape pressure resultant from global climate change awareness is specifically cited as motivation for the development's sustainability orientation. Sustainability, as a national, political ideology also serves to pressure municipalities. Thus, the pressure on urban developers to align their actions with ecological, economic, and social sustainability objectives is felt both nationally and internationally. However, as Sweden is taking an eco-modern approach, sustainability is prioritized alongside economic growth and social equity. Given Sweden's decentralized urban planning scheme, municipalities may prioritize the three slightly differently, which could potentially hinder the full adoption of niche-innovations into Swedish society. Therefore, a nationally coordinated response to sustainable development with regards to the nature and timing of niche-innovations may not be possible. This indicates that a system of decentralized urban planning has the potential to reinforce regimes by preventing wide-spread adoption of niche-innovations, and, by extension, full regime shifts. On the other hand, this decentralized system gives municipalities the flexibility to experiment with different innovations. In this scenario, many different innovations can be tested simultaneously and, with some intermunicipal communication, those innovations that are most successful can be implemented more broadly. This indicates that a system of decentralized urban planning also has the potential to test many innovations simultaneously in order to determine which has the best chance at solving problems within the regime. Ultimately, the landscape pressure resultant from a decentralized urban planning system depends on the strength of voluntary communication between municipalities about both the success of niche-innovations, and how they balance national sustainability, economic, and social equity goals.

6 Chasing Transitions

6.1 Brunnshög's Epistemology

The epistemologies summarized in Table 1 classify approaches that urban experiments may take when driving systemic change for sustainability. I will classify Brunnshög's approach to sustainable development using these epistemologies to further address the first research question: How do Brunnshög's proposed innovations intend to challenge dominant socio-technical systems? An in-depth look at the relationship between specific innovations and the regime is provided in section 5.2.2.

Brunnshög's development most closely aligns with the first epistemology: transforming urban mechanisms and political ecologies, whose primary drivers of change are political, economic, ecological, and technological. Brunnshög's primary stakeholders do include the local government (Lund Municipality, including the Department of Waste Management), as well as infrastructure and technology providers (contractors and Kraftringen respectively). The main socio-technical systems (STS) being challenged through experimentation in Brunnshög include energy, waste, and transport, as suggested by the epistemology. This epistemology also prioritizes a reduction of the city's carbon and ecological footprints alongside continued access to resources that support economic growth, protect local assets, and uphold present living standards, which is an inherently eco-modern statement, thus aligning well with the perspective of stakeholders in Brunnshög.

Furthermore, Brunnshög's development patterns do not align strongly with the second epistemology, configuring urban innovation systems for green economies, because consumption and production patterns are not the developers' main concern. Although, encouraging a circular or sharing economy may serve to reduce some consumption. The third epistemology, empowering urban grassroots niches and social innovation, de-emphasizes technical solutions in favor of social and cultural initiatives that are driven by civil society actors. While Brunnshög also has a focus on social and cultural aspects that are not completely encompassed by the first epistemology, government actors are those driving development in the area and technical solutions have a prominent role. Therefore, the first epistemology best encompasses the eco-modern approach to urban experimentation in Brunnshög.

6.2 Transition Pathway Determination

In this section, I identify Lund's transition path and how Brunnshög may contribute to its realization to answer the second research question: What potential does Brunnshög's development have to contribute to a sustainability transition in Lund?

Within Sweden, sustainability and sustainable development have been prevalent in policy and practice throughout the last two decades. Thus, the transition to a more sustainable society has also been underway during this period of time. Therefore, Brunnshög's niche-innovations do not necessarily differ greatly from the current norms. Instead, it seems, the niche-innovations being adopted in Brunnshög have found a place to continue their maturation process. They are slowly being adopted into the regime to solve problems. Brunnshög is unique because all the innovations are being adopted simultaneously in the same space and, perhaps, that is the true experiment.

It is also clear that regime actors are driving this urban experiment. Changes within the niche are to the benefit of incumbent actors trying to change the course of development across many STS. Although sustainability is highly prioritized, it is unlikely that any action will be taken that negatively impacts economic growth, which will limit the potential of urban experiments to motivate quicker or extremely radical action for sustainability. Although the pace of action taken to mitigate global warming has increased in recent decades within Sweden, there is no indication that the economic system itself will change in ways that drastically reduce consumption and production patterns, or force lifestyle changes. Instead, the focus is on reducing the carbon and ecological footprints associated with such actions, so that the current living standard is upheld. Once again, sustainable development in this case can be squarely characterized as eco-modern.

This information indicates that Lund currently embodies the transformation transition path, in which a new regime eventually evolves out of the old one and regime actors remain constant. In the case of Brunnshög, regime actors are not resisting change, but encouraging it, albeit with their own economic agenda. Re-orientation towards sustainability has been ongoing for 20 years, and urban experiments like Brunnshög serve to test innovations and/or embed those that have proven to work elsewhere, more strongly within the regime. However, in the end, the regimes' most basic structures remain.

Although the current transition path is clearly oriented towards that of transformation, there is cause to believe that a shift to the reconfiguration pathway could take place. Similar to the path of transformation, reconfiguration also relies on the regime's adoption of niche-innovations. However, if enough innovations are adopted at a quicker pace, then new combinations between innovations may prompt structural changes within the regime. These new combinations are known as knock-on effects. Brunnshög's niche-innovations are influencing a single space and tackling challenges across multiple STS. This arrangement provides ample opportunity for knock-on effects to develop since STS are interconnected. Perhaps if these effects prove useful, they may also be adopted within the regime and motivate more substantial change.

6.3 Challenges and Limitations of the MLP

Applying the MLP to this case study was challenging. Within Geels' literature, the MLP is primarily applied to better understand the transition of a single regime (Geels, 2002, 2006). Additionally, examples are generally historic, and thus representative of complete transitions (Geels & Schot, 2010). In the instance when Geels et al. (2016) did examine ongoing transitions, the analytical time periods were provided, but not explicated and the analysis still centered around a single regime. Therefore, determining which time period should be considered for the ongoing transition in Sweden, as it relates to Brunnshög, was challenging. For example, should the norms created over the last 20 years be considered as the regime when compared to Brunnshög, or should norms existent before the current transition began characterize comparative regimes? Of course, if the former option is chosen, then the current regime formation is still informed by changes that took place at the start of the current transition period. In this study, the former was chosen, but perhaps the latter perspective could also be justified, which would produce different results. Additionally, this study considers many different innovations simultaneously, so the analysis must incorporate many different, but interconnected regimes, which increases complexity and decreases the depth with which individual STS could be analyzed during this project. Ultimately, my engagement with this theory has made clear the lack of guidance about defining a time period for the analysis of an ongoing transition or how the MLP may be effectively applied to understand a transition resultant from smaller transitions taking place across multiple regimes.

6.4 Looking Towards the Future

Ultimately, much of Brunnshög's development still remains a vision. Although the research facilities, ESS and MAX IV, will soon be complete, and the construction of Södra Brunnshög is well underway, the full development of this area is expected to take 40 years. Therefore, it is imperative that this case is followed closely if its true influence on Lund's transition to sustainability is to be realized. Additionally, Brunnshög is not the only urban experiment in Sweden, much less Skåne. It would be meaningful to better understand the combined effects of so many experiments under such a decentralized planning system. Are municipalities interpreting national policy differently or prioritizing different innovations? Are they duplicating work or repeating mistakes? How does this decentralized system affect the national transition path to sustainability? Much can still be gleaned from analyzing urban experiments individually and collectively within Sweden. Finally, the uptake speed of innovations within the regime and proliferation of knock-on effects will define whether or not Lund's transition pathway remains one of transformation or shifts to reconfiguration. Thus, the progress of niche-innovations specifically need to be followed closely in relation to Lund's dominant regimes and landscape pressure.

7 Conclusion

The conflict between urbanization and global warming necessitates sustainability transitions in urban areas. Thus, some cities focus on becoming loci for urban experimentation aimed at revealing sustainable system alternatives. Lund is such a city and the developing district of Brunnshög is its urban experiment. From a multi-level perspective, Brunnshög's development and niche-innovations help characterize Lund's transition pathway. Brunnshög's primary niche-innovations fall within four socio-technical systems: transportation, energy and heating, waste management, and food production. These innovations compete with the transport regime and, to a lesser extent, the food production regime but are otherwise symbiotic. Disruptive landscape pressures, which derive from Sweden's eco-modern political ideology and growing global awareness of climate change, are being felt at the regime level. It remains to be seen, however, if the decentralized nature of urban planning in Sweden serves to reinforce the dominance of current regimes by preventing a nationally coordinated response to sustainable development, or if the decentralized system pressures regimes by encouraging broad experimentation leading to the adoption of exceptional innovations across municipalities. This outcome depends on the municipalities' willingness to communicate and coordinate efforts.

Brunnshög's development aligns most closely with an eco-modern epistemology for urban experimentation since prioritization is given to reducing the city's ecological and carbon footprints while maintaining economic growth and current living standards. The social component of Brunnshög's development plan, which focuses on providing common meeting places and experiences, is not completely encompassed by this epistemology. However, this social component also has an economic motive, as it exists in part to increase collaboration and promote creativity and innovation. Ultimately, this classification reveals that although regimes are changing, niche-innovations are not challenging their basic structure. This revelation, coupled with the fact that niche-innovations are largely symbiotic and incumbent regime actors are primary stakeholders, shows that Brunnshög contributes to the current transformation transition path evident within Lund. There is potential though for this transition path to shift to reconfiguration. Given that socio-technical systems within urban areas are interconnected, it is probable that niche-innovations from different regimes could combine and create knock-on effects capable of restructuring regimes. Brunnshög's development must be followed closely over the next few decades to determine which transition path it ultimately contributes to.

Future research should seek to understand the collective effects of urban experiments across the country and how Sweden's decentralized system affects its overarching sustainability transition. The multi-level perspective framework could also be refined to better facilitate the analysis of ongoing transitions, as well as the analysis of multiple niche-innovations across many interconnected regimes.

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