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Changing Energy Supply Through Urban Sustainability Experiments

A comparative case study of Sonderborg and Copenhagen, Denmark

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CHP	Combined heat and power
CPH	Copenhagen
COP15	Copenhagen Climate Conference
CTR	Centralkommunernes Transmissionsselskab I/S
HOFOR	Hovedstadsområdets Forsyningsselskab
MW	Megawatt
PSO	Public Service Obligation
SE	Syd Energi
SONFOR	Sonderborg Forsyning
SDU	Syddansk Universitet
VEKS	Vestegnens Kraftvarmeselskab

Abstract: Climate governance is diversifying as the traditional multilateral approach is complemented by more autonomous and experimental reactions. The aim of this thesis is to enquire into this new kind of climate governance. Through a comparative case study of two urban climate change experiments in Denmark, the thesis first explores mechanisms that aid and hinder the achievement of experiment objectives, and second examines how the experiments' geographical context influences these mechanisms. The case analyses suggest that both experiments are influenced in a very similar manner by economic opportunity, political and technological embedded-ness and conflict, while the experiments' very different urban forms create dissimilar barriers and opportunities.

Keywords: urban climate change experiments, urban governance, systemic change, climate change.

CHAPTER 1

INTRODUCTION

In an age of climate change, contemporary society faces multiple and complex challenges. While scientists struggle to fully comprehend the phenomenon and its consequences, societies juggle the task of governing in response to this partially understood situation. In recent years, scholars have proposed, that the latter issue, climate governance, is changing in multiple ways. It is diversifying and the traditional multilateral approach is complemented by more autonomous, experimental reactions (Hoffmann 2011). So-called 'urban sustainability experiments' or 'urban climate change experiments' (here used interchangeably) constitute part of this new wave of initiatives and form the theoretical point of departure for this thesis. Vanesa Castán Broto and Harriet Bulkeley have played an important part in advancing the study of urban climate change experiments. They define the concept in terms of three parameters (Broto and Bulkeley 2013:93):

> *First, an intervention is experimental when it is purposive and strategic but explicitly seeks to capture new forms of learning or experience; second, an intervention is a climate change experiment where the purpose is to reduce emissions of greenhouse gases (mitigation) and/or vulnerabilities to climate change impacts (adaptation); third, a climate change experiment is urban when it is delivered by or in the name of an existing or imagined urban community.*

Urban sustainability experiments are thus geographically confined approaches that test and uncover untried ways of responding to climate change. Research on the topic has developed an understanding of the emergence and prevalence of experiments as well as the different actor- and stakeholder involvements (Bai *et al*. 2010; Bulkeley and Betsill 2003; Bulkeley and Broto 2013; Broto and Bulkeley 2013). Having established a comprehensive account of the phenomenon, research increasingly engages with a further examination of the initiatives' ability to more fundamentally alter urban responses to climate change – essentially their effect or success. As the number of urban climate change experiments increase around the world it is particularly important to investigate whether this type of climate governance is an effective and successful response. It is the aim of the thesis to contribute to this line of research; however, assessing the effect of climate change experiments is a puzzling nature, as Hoffmann (2011:156) illustrates:

> *The metrics that we use to evaluate the effectiveness of climate change experiments are not clear. On the one hand, their ultimate worth depends on achieving a stabilisation of the climate system and a turn to a low carbon economy. Yet, tracing the causal impact of climate experiments on these outcomes (should they come to pass) is virtually impossible given the vast array of forces and dynamics that would contribute to such a transformation. Yet we*

> *can evaluate the impact and effectiveness of climate governance experiments more modestly, namely if and how they contribute to trajectories of change.*

Hoffmann (2011) situates the question of effect within the perspective of the entire climate system and attempts to define a more narrow scope of investigation based on an assessment of ‘trajectories of change’. Nonetheless, it remains unclear how we determine that an experiment contributes to change, and how we assess that the experiment is ‘successful’. Hodson and Marvin (2011) attempt to tackle this challenge. They argue that the analytical framework for assessing effect should be two-fold, including first, “an ‘outcome’ indicator of ‘effectiveness’” and second “a processual and contextual view of ‘effectiveness’” (Hodson and Marvin 2011:66). The initial ‘outcome-assessment’ considers the concrete aims and objectives stated in the experiment vision, and determine the extent to which these aims and objectives have been achieved. The more ‘contextual-assessment’ captures the processes that underpin the attempt to realise the experiment aims and objectives, and examines the mechanisms that aid and hinder the realisation of the experiment. This analytical framework assumes that realising the vision of an urban climate change experiment will lead to a greater degree of sustainability. The framework determines whether the vision is realised and uncovers reasons why this is the case.

The thesis applies Hodson and Marvin’s (2011) analytical approach to assess the effect and success of two urban climate change experiments. Focusing specifically on goals related to energy supply, the thesis examines two experiments that aim to achieve a transition to carbon neutrality. Previous research that study the success of urban climate change experiments consists mainly of individual qualitative case studies and several quantitative surveys with larger sample sizes (Wolfram and Frantzeskaki 2016). Thus, this thesis’ qualitative comparative nature tries to bridge an empirical gap in the literature. The comparative design also attempts to instil a more spatially informed analysis that allows for a more systematic investigation of how different urban contexts influence the experiments.

1.1 Purpose and Research Questions

Focusing specifically on two urban climate change experiments in Denmark, ‘ProjectZero’ in Sonderborg and ‘The CPH 2025 Climate Plan’ in Copenhagen, the purpose of this thesis is two-fold. First, in an attempt to study the success of urban climate change experiments the thesis explores the mechanisms that aid and hinder local transitions to carbon neutrality. To narrow the scope of analysis, the thesis focuses on initiatives related to energy supply, which in the thesis is defined as the production of energy (the processes of turning resources into useable forms of energy), and the distribution of energy (the processes of providing energy to the end-user). Energy supply is chosen because it accounts for the greatest share of carbon reductions in both experiments, and is therefore critical for achieving a transition to carbon neutrality.

Second, the thesis attempts to examine how geographical context, the capital city context in Copenhagen and the sub-urban context in Sonderborg, influences the success of the experiments. A geographically informed analysis helps to reveal how place specific characteristics impact the mechanisms that aid and hinder the transition. The thesis thus attempts to answer the following research questions:

1. With particular reference to energy supply, what mechanisms aid and hinder the local experiments' attempted transition to carbon neutrality?
2. How are these mechanisms influenced by the experiments' geographical context?

1.2 The Case Studies

ProjectZero and the CPH 2025 Climate Plan both set out to make their respective municipalities carbon neutral. This is to be achieved by 2025 in Copenhagen, and 2029 in Sonderborg, more than 20 years before the Danish government aims to make the country independent of fossil fuels (Klima- og Energiministeriet 2011). The geographical location of the experiments is shown in figure 1 below.

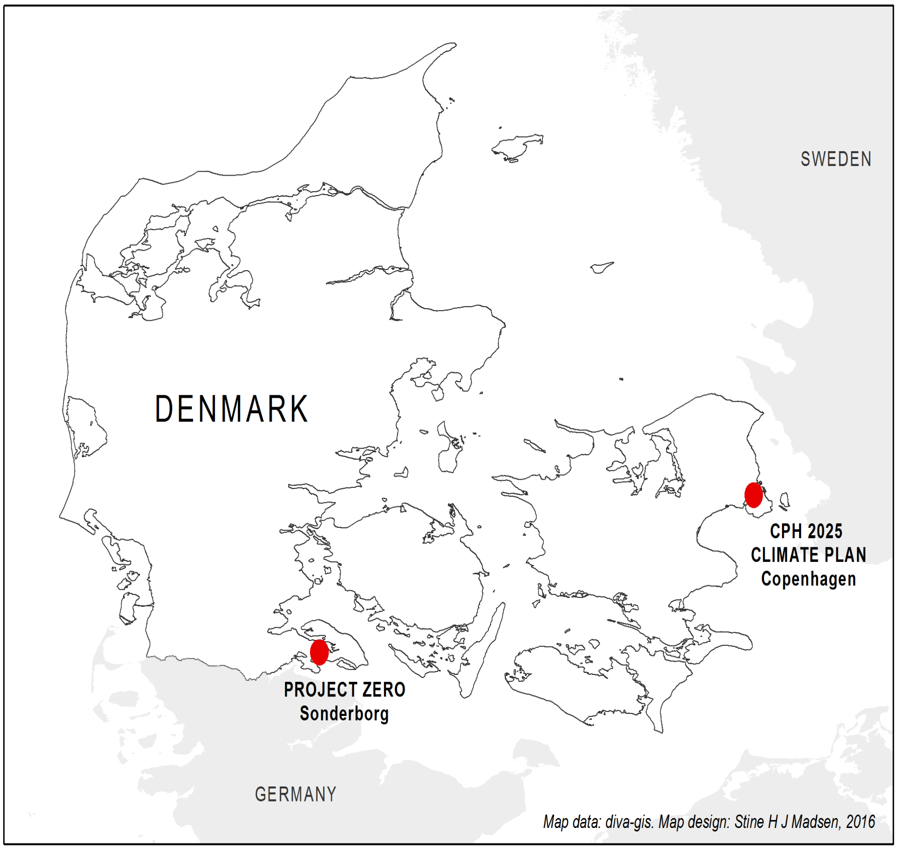

Figure 1: Map showing the geographical location of the two case studies

ProjectZero and CHP 2025 Climate Plan are theorised as urban climate change experiments based on Broto and Bulkeley's (2013) definition, which is quoted above. First, the initiatives are experimental in that they set out to achieve climate related objectives through a process of trial and error. Both projects emphasise that the plans for implementation must remain adaptable, since particularly the later stages of implementation are expected to depend on new technologies and practices that are not developed or known at the outset of the vision (ProjectZero 2009a; City of Copenhagen 2012). Second, the initiatives are climate change experiments because they aim to reduce green house gases through a transition to carbon neutrality (mitigation). Third, the initiatives are urban climate experiments because they take place in existing urban communities. This is very clearly the case for CHP 2025 Climate Plan, which is delivered in the municipality of Copenhagen - the central part of the Danish capital city. For ProjectZero the case is slightly different. ProjectZero sets out to achieve carbon neutrality in the municipality of Sonderborg, which is a political-administrative entity created from the merger of seven smaller municipalities during the 2007 national reform in Denmark. The ProjectZero initiative is thus engaged, not with one single city, but with a territory that consists of multiple urban, semi-urban and rural areas. Although ProjectZero is not a single urban area such as Copenhagen it is argued here that ProjectZero can still be conceptualised as an urban experiment because the municipality of Sonderborg is the scale at which energy supply is mainly organised. According to Späth and Rohracher (2011) this organisational characteristic can also define a confined urban space. The very different urban contexts have been chosen on purpose to better investigate how different geographical context impacts on the experiments.

However, a key justification for comparing the cases is that they in many other respects are quite similar. They are situated in the same national context within which they are both considered frontrunners (Sperling *et al.* 2011). Their overall visions are almost identical and their implementation processes are very alike, too. Both experiments have moreover been in a phase of implementation for a considerable amount of time, four years in Copenhagen and six years in Sonderborg, which justifies an exploration of the mechanisms that have aided and hindered the process of implementation so far. However, the experiments differ in two particular respects. As mentioned, their urban contexts are purposefully different, but their organisational set-ups are also contrasting. The CPH 2025 Climate Plan is a municipal undertaking while ProjectZero is a public-private partnership. In terms of the purpose of the research we are primarily interested in the impact caused by the differing urban contexts, and so the analysis will attempt to tease out whether place specific impacts are related to geographical context or the experiment's organisational set up.

1.4 Thesis Structure

The thesis is divided into eight chapters. Chapter 2 succeeds this introduction with a theoretical background that presents strands of literature related to urban climate change experiments. Chapter 3 outlines the thesis' methodological outset and the specific methods that are used to carry out the empirical research. Before diving into the case descriptions in chapter 5 and 6, chapter 4 provides a foundational understanding of energy supply in the Danish context. Chapter 7 brings together the case descriptions and draws on knowledge from the national context when carrying out a comparative analysis. Finally, chapter 8 explores main conclusions and zooms out to reflect on the research more broadly.

CHAPTER 2

THEORETICAL BACKGROUND

The research on urban climate change experiments draws on multiple academic strands particularly urban studies and systemic change theory. The theoretical background is divided into three sections in order to situate urban climate change experiments within these different academic traditions. First, urban climate change experiments are introduced with regards to large developments in climate governance and the rise of experimentation. Second, characteristics of urban climate change experiments are outlined and the increasing role of cities in climate governance is considered. Third, the ability of systemic change theory to inform our understanding of urban climate change experiments is explored.

2.1 Developments in Climate Governance

To understand the theoretical underpinnings of urban climate change experimentation, the starting point for this theoretical background is a brief introduction to the evolution of climate governance. Climate governance is a current and popular concept, which has been defined and understood in multiple ways. Here we rely on Jagers and Stripple's (2003:385) understanding of the phenomenon. They refer to climate governance as: "all purposeful mechanisms and measures aimed at steering social systems toward preventing, mitigating, or adapting to the risks posed by climate change". This section demonstrates that climate governance has increasingly diversified and that the traditional multilateral approach is complemented by more autonomous, experimental reactions including urban climate change experiments. It is moreover argued that the rise of experimental approaches to climate change is linked to two simultaneous developments. First, a discontent with traditional approaches to climate governance, and second a broader fragmentation and restructuring of the state reflecting governance theory more broadly.

Initial scientific evidence of the link between industrialisation and environmental degradation triggered the 1972 UN Conference on the Human Environment in Stockholm and initiated the multilateral approach to climate change (Bernstein *et al*. 2010; Hoffmann 2011). The multilateral approach to climate change is characterised by summits where the world's nation states attempt to reach international agreement where individual countries commit to specific reduction targets. The summit in Stockholm sparked global discussion about the future of the Earth's environment, and for the first time tried to reach an environmental policy consensus (Najam and Cleveland 2003). During the 1980s and 1990s, the multilateral approach to climate change consolidated as scientific evidence of climate change strengthened. The number of summits intensified and the multi-lateral approach seemed increasingly self-evident. The multi-lateral approach was considered appropriate due to the transnational nature of climate change – a global problem requires global solutions. Moreover, the approach gained prominence after the 1987 Montreal Protocol, which successfully managed to tackle ozone depletion – there was a belief that this success could be replicated (Hoffmann 2011).

Although building on similar ideas as the Montreal Protocol, climate change agreements have been largely unsuccessful. With particular reference to the Kyoto Protocol, arguably the centrepiece of the multilateral approach, Barrett (2005) explains that the inability of the agreement to discourage free-riding is a key reason for its failure. Due to the lack of international enforcement, free-riding is undermining agreements. A deeper conflict is arguably also at work. Although economic growth and environmental protection are theoretically brought together under the concept of sustainable development, states have been reluctant to commit to agreements (Bernstein 2002). Academics explain this trend with regards to economic interests; countries prioritise domestic economic growth over global environmental protection (Barrett 2005; Hoffmann 2011). Despite these challenges the multilateral approach to climate change is still going strong. In December 2015, leaders of the world came together in Paris to sign the first-ever global, legally binding treaty, where almost 200 countries commit to reducing greenhouse gasses. Commentators suggest that the agreement represents an important political step, but it is still too early to say whether the Paris Accord will be a positive turning point for the multilateral approach (Davenport 2015; Goldenberg *et al.* 2015).

A new narrative is emerging alongside this formalised and top-down approach to climate change. Bottom-up approaches are proliferating around the world, arguably representing a new landscape of climate governance that goes 'beyond the state' (Biermann and Pattberg 2008; Okereke *et al.* 2009). Hoffmann (2011:5) finds that "cities, counties, provinces, regions, civil society, and corporations are responding to climate change independently from, or only loosely connected to, the "official" UN-sponsored negotiations and treaties". This means that a host of communities and organisations take it into their own hands to adapt or mitigate to climate change. It is suggested that an increasing number of non-state actors partake in climate governance due to "frustration with the multilateral approach […] a sense of urgency about climate change, and even profit and power" (Hoffmann 2011:5). This proliferation of initiatives should not be seen as multiple disjointed efforts, but instead as a larger complementary approach to climate governance (Bernstein *et al.* 2010). Hoffmann (2011:5) defines the shift as a move to an 'experimental approach' to climate change.

The rise of the experimental approach to climate change should be understood against the backdrop of larger developments in society and governance theory. Since the 1990s, scholars have identified a 'governance turn' in the broader social sciences, which represents multiple processes through which state authority is restructured. State space, responsibilities and regulatory tasks are changing through simultaneous processes of state down-scaling and up-scaling, which is creating new supranational and subnational political regimes (Brenner 2004; Jessop 1990). Thus, the rise of the experimental approach to climate change, where action is fragmenting and non-state actors come to play an increasing role, follows a larger process of fragmenting political authority. It is arguably the combination of this fragmented political authority and the discontent with traditional approaches to climate change that has sparked the experimental approach, and which has created political space for it to flourish (Bulkeley and Broto 2013).

2.2 Urban Climate Change Experiments

Urban climate change experiments are understood as part of this larger phenomenon of climate governance experimentation. Following Hoffmann's (2011) theoretical developments of the experimental approach to climate governance, Bulkeley and Broto (2013) assert that the growing number of urban climate initiatives can similarly be considered intended governance interventions. Bulkeley and Broto (2013) survey urban climate change experiments across 100 global cities to provide overarching insights about the phenomenon. Their empirical work reveals that urban climate change experimentation is not geographically confined, but prevails across the global North as well as the global South. They find that urban sustainability experiments have emerged more recently; out of the 627 experiments they identify, 79% were initiated after 2005. Bulkeley and Broto (2013) moreover discover that a majority of the experiments are concerned with energy consumption and production, and that technical experiments predominate the sample. In terms of actors, public-sector actors lead most of the experiments. Civil society and private actors are also involved in experiments, however, most often in combination with public actors. Across their sample, public-private partnerships are particularly popular.

The recent growth of urban climate change experiments parallels an increasing understanding that cities are important sites for responding to climate change. During the past two decades, the issue of climate change has increasingly been cemented on the urban government agenda and further institutionalised through international networks such as Cities Climate Leadership Group and Local Governments for Sustainability, where mayors and local governments collaborate to excel climate action at the local scale (Bulkeley *et al*. 2011). Multiple reasons are given as to why urban areas are important sites for climate change governance. First, cities are believed to possess institutional advantages when it comes to climate change response. This argument is based on the understanding that local authority is generally in charge of the city's public services and systems of infrastructure, and therefore able to more directly make emission-reducing changes to these systems. Second, local initiatives are arguably better equipped to mobilise multiple stakeholders in the area. Local initiatives can use their understanding of local impacts to tailor information and campaigns, which helps make the issue more relevant to concerned stakeholders (Coutard and Rutherford 2010).

Third, local responses are considered more effective because they take the local context into account. Compared to regional or national scale strategy, the local responses increasingly rely on an understanding of local needs and local opportunities. Finally, some cities may benefit from economies of scale due to higher population densities and a more compact urban form (LSE Cities 2014). In theory climate governance at the scale of the city offers more effective policies (Coutard and Rutherford 2010).

Although the scale of the city is the analytical point of departure in urban sustainability experiment research, literature on the topic illustrates that connections to other political scales are also pronounced and important. Some authors even approach cases with a multi-level governance framework that looks specifically at how different policy levels interact. For instance, Hodson and Marvin (2009) find that London's attempt to transition to a hydrogen economy is intimately linked to and influenced by national policies. The study shows that political influence works both top-down and bottom-up. On the one hand the urban transition is influenced by national policies and legal regulations, but on the other hand London is able to influence national policies, particularly because national government is positioning London as a national exemplar and thus have invested interests in the city's transition.

This embedded nature of urban sustainability experiments creates a complicated governance situation. As mentioned, Bulkeley and Broto (2013) find that urban climate change experiments are often characterised by multiple internal actors, which means that the external relations act as an additional influence on top of an already heterogeneous group of internal actors. As such many urban climate change experiments navigate and negotiate between multiple actors and influences, and are therefore often characterised by contestation and some times even conflict (Coutard and Rutherford 2010; Monstadt 2007). Power consequently plays an important role and urban climate change experiments can be understood as fundamentally political, since having the power to decide when and how to intervene is a powerful political manoeuvre (Shove and Walker 2007).

The political dimensions of transitions to sustainability are messy and often criticised. Meadowcroft (2011) outlines three reasons why political engagement with the sustainability agenda is so difficult. First, multiple political issues compete for attention and resources. Unlike sustainability related initiatives, which may first bring benefits decades into the future, many other political initiatives provide more immediate and concrete consequences, and might therefore be easier to politically prioritise. Second, when it comes to sustainability an underpinning lack of certainty overwhelm action. It is difficult to navigate politically when the consequences of climate change are uncertain and when the implications of action or inaction are unknown. Finally, a transition interrupts established interests. New costs and benefits arise as a result of transition, and the distribution of these is contested. Meadowcroft (2011:72) consequently argues:

> *…a real (as a opposed to a rhetorical) politics of sustainability implies hard choices: picking priorities (and setting aside other projects); making decisions that are almost guaranteed to be suboptimal and assuming current costs to hedge uncertain future risks; and cutting through distributional entanglements.*

The question is if urban climate change experiments support a ‘real’ move to sustainability. As cities and urban experiments are heralded as key sites for sustainable innovation and climate governance it is increasingly important to assess whether urban sustainability experiments bring about fundamental changes to climate change mitigation and adaptation. In trying to address this issue, research on urban sustainability experiments draws on theoretical understandings developed in systemic change literature. We now turn to this literature to explore how it further informs our understanding of urban climate change experiments and to identify gaps that continue to exist in the research.

2.3 Cities and Systemic Change for Sustainability

The literature on urban climate change experiments adapts systemic change frameworks and concepts to enquire into the patterns and dynamics of urban change that results from the new experimental initiatives. The systemic change literature is concerned with fundamental shifts in socio-technical systems. Socio-technical systems are elaborate systems that provide societal functions and services such as transportation, communication and resources (Geels 2004). Socio-technical systems develop over time into very complex arrangements where institutional, economic, organisational and social configurations become both interrelated and dependent on each other (Markard 2011). A socio-technical transition can cause a radical change in the pre-existing socio-technical system, but this is a complicated and extensive process that involves reshaping technology, infrastructure and human practises (Kemp 1994). Recent work on systemic change has taken a specific interest in sustainability. Here scholars study the attempt to direct socio-technical transitions towards sustainable configurations, so-called sustainability transitions (Markard *et al*. 2012).

The contributions from systemic change theory can arguably be divided into three overarching themes. First, by starting to use a ‘transition’ vocabulary, sustainability aspirations are visualised and oriented towards more long-term changes. The socio-technical vocabulary moreover emphasises that these long-term changes result from the co-evolution of both technological and societal developments (Meadowcroft 2011). Second, the systemic change theory provides research on urban climate change experiments with a host of concepts and frameworks useful for exploring patterns and dynamics of urban change. For instance, the multi-level perspective and strategic niche management provide avenues to uncover how fundamental changes are accelerated or slowed down. Strategic niche management specifically deals with how transitions can be accelerated through the creation of protected spaces that allow experimentation to evolve (Schot and Geels 2008). Urban areas are conceptualised as such protected spaces and it is argued that selection pressures are different in urban areas, which help facilitate the emergence and growth of experimental governance approaches (Bulkeley *et al*. 2015). Finally, systemic change theory has initiated the development of a more practical transition management approach that suggests techniques to guide changes. An example is visioning exercises where stakeholders partake in interactive processes to define problems and future practical activities (Meadowcroft 2009). Transition management is not a finished solution as debates flourish about whether it is possible to 'manage' these large-scale transitions in the first place. Nonetheless, the research provides a pool of knowledge that scholars who are engaged with urban sustainability experiments can tap into.

The cross-fertilisation between urban studies and systemic change literature not only advances knowledge of urban sustainability experiments, but also starts to address a key criticism of the systemic change literature more generally. Scholars from the field of geography (Coenen *et al*. 2012; Hodson and Marvin 2010; Truffer and Coenen 2012) argue that sustainability transition research has outlined the emergence and evolution of changing socio-technical systems with a spatial blindness. Coenen *et al*. (2012) contend that the literature on sustainability transition is characterised by two main weaknesses, which both result from this omission of geographical consideration. First, it is argued that the literature on sustainability transitions neglects the importance of spatial context and avoids to ask questions about where transitions geographically take place and why this is the case. Second, Coenen *et al*. (2012) find that the literature lacks an appropriate use of geographical scale. Systemic change frameworks such as the multi-level perspective draw on conceptual understandings of scale rather than geographical understandings. It is argued that these geographical disregards hamper the ability to develop a well-reasoned theory of sustainability transition, and that further theoretical developments should draw on spatial considerations and pre-existing spatial understanding to better explain why some transitions fail and others succeed.

In light of this criticism research on urban climate change experiments are considered a particularly "productive line of research" because it situates a geographical space, the city, at the centre of the transition research (Truffer and Coenen 2012:14). Nonetheless, Wolfram and Frantzeskaki (2016) identify an empirical gap in the research on urban climate change experiments, which if addressed might further advance geographical understanding. They find that current research consists mainly of individual qualitative case studies and several quantitative surveys with a larger sample size. Qualitative comparative research looking at two or more urban areas has barely been done. Consequently, they argue, that future research should systematically enquire into how different urban contexts influence the attempted transitions. This can methodologically be achieved through comparative studies where differences and similarities are identified (Hansen and Coenen 2015). The thesis aims to address this empirical gap and to situate the concern for geographical space at the centre of analysis by comparing urban climate change experiments in two different urban settings.

CHAPTER 3

METHODOLOGY

3.1 Philosophical Assumptions

This thesis relies on the interpretive framework of critical realism, which provides both a critique of, and an alternative to, the belief systems of positivism and social constructivism. As such the thesis takes a certain approach to social science research, and is underpinned by both ontological and epistemological assumptions. Ontological assumptions refer to the way we understand the nature of reality, while epistemological assumptions refer to our understanding of what counts as knowledge and what can be studied. These philosophical assumptions are important because they impact the research design and analysis (Sayer 2000).

Ontologically, critical realism proposes that the world exists as 'something' separate from both our knowledge of the world, as well as the language and imagination we use to grasp and describe reality (Sayer 2000). Positivists believe in a similar objective world, however they restrict their understanding of reality to everything that can be measured and observed. Critical realists grant less importance to the observer, and instead advance that reality exists independently from our ability to observe it. Thus, critical realists do not claim to be in possession of a real or true understanding of phenomena, but instead acknowledge that the world is also made up of social constructions and subjective interpretations. Even so, critical realists do not commit fully to social constructivism where the ontological belief is that reality is completely subjective and that all theories of knowledge are equal. Rather, critical realists contend that knowledge in natural sciences sometimes has a superior understanding of the natural world and that "the achievements of applied science are testament to a greater accuracy of modern knowledge compared to beliefs" (Edwards *et al*. 2014:5). These assumptions impact the role of the researcher. From the perspective of critical realism, social scientists interpret and try to explain the social world rather than construct it (Sayer 2000).

When trying to describe, interpret and explain, critical realists rely on a causal approach. This means that the researcher sets out to not only describe an event, but to also try to explain what mechanisms caused that event to happen. Thinking conceptually is often an important part of this endeavour and critical realists rely on previous theoretical ideas to inform new data (Edwards *et al*. 2014). The goal of explanation has critical epistemological implications, "[i]t justifies the study of any situation, regardless of the number of research units involved, but only if the process involves thoughtful in depth research with the objective of understanding why things are as they are" (Easton 2010:119). When investigating these underlying processes, critical realists assume an open system conceptualisation. Unlike a closed systems approach where the research events are thought to be isolated from external impacts, an open systems approach acknowledges that particular situations and larger circumstances impact individual events (Sayer 1992).

Relying on an interpretive framework of critical realism has a number of implications for the thesis. First, it helps to justify the thesis' qualitative approach and its case study research design; both issues will be discussed in greater detail in the following section. Second, critical realism's philosophical assumptions regarding explanation, causation and the open system conceptualisation are also reflected in the two-fold purpose of the research question. The first research objective explores the mechanisms that aid and hinder the experiments' transition to carbon neutral energy supply. To explore these mechanisms the thesis describes the goals that are set out in each of the two urban sustainability experiments, and for each experiment it tries to explain the underlying mechanisms that either aid or hinder the goal in being achieved. The open system conceptualisation lies at the heart of the second research objective, which is to explain how these underlying mechanisms in each of the experiments are influenced by their respective geographical context.

3.2 Research Design

The thesis undertakes a qualitative, comparative case study. A qualitative research approach is suitable because the purpose of the research is to explore and holistically comprehend issues related to urban climate change experiments. Rather than a quantifiable and controlled examination, a qualitative approach encourages the researcher to study phenomena in their natural context, which provides the researcher with a better possibility of understanding and interpreting the phenomenon (Denzin and Lincoln 2005). A case study design also complements the intentions of the qualitative approach well. The case study approach allows the researcher to explore "a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information" (Creswell 2013:97). The case is referred to as "a bounded system", which means that it can be described within certain limits (Stake 1995:2). In order to carry out a more focused analysis it is important to define the boundary of a case.

This thesis develops an in-depth understanding of two cases from Denmark, an urban sustainability experiment in the municipality of Sonderborg and one in the City of Copenhagen. Both experiments are made up of a broad range of initiatives that aim to achieve carbon neutrality. To limit the scope of analysis, the thesis only considers goals that are related to energy supply, which here refers to both the production of energy, the process of turning resources into useable forms of energy, and distribution of energy, the process of providing energy to the end-user. The focus on energy supply is chosen because it accounts for the greatest share of carbon reductions in both experiments, and is therefore critical for achieving a transition to carbon neutrality.

The two cases have purposely been selected for a number of reasons. The experiments are first of all similar in multiple respects. They are both situated in the Danish national context, which helps control for context variables. Both urban sustainability experiments are also considered frontrunners in the Danish context (Sperling *et al.* 2011). Their goal of carbon neutrality and their overall implementation plans are also very similar. Moreover, both experiments have been in a phase of implementation for a considerable amount of time, 4 years in Copenhagen and 6 years in Sonderborg, which justifies an exploration of their hitherto progress. However, the experiments differ in two particular respects. Their urban contexts and organisational set-ups are very contrasting. The CPH 2025 Climate Plan is a municipal undertaking, which is established in the capital City of Copenhagen, while ProjectZero is a public-private partnership set out to impact the semi-urban area of Sonderborg. In line with a 'maximum variation sampling strategy' (Creswell 2013:156), it is hoped that the variation in these aspects will generate different perspectives. On a practical note, the decision to study the case of ProjectZero was also motivated by the author's previous knowledge and connection to the experiment. From 2010-2011, I worked as a student assistant in ProjectZero's secretariat. This pre-existing connection enabled easier access to some of the stakeholders in the area.

The research neither aims nor claims to be representative of urban climate change experiments in Denmark or any other place. The cases do not represent a sample and do not aim to provide any statistical generalisation. Instead, a qualitative case study like this one aims first and foremost to develop an in-depth understanding of both cases. Through the subsequent task of comparison theoretical propositions may be generated (Yin 2009), and these may in turn help to inform the study of other urban sustainability experiments. Using Stake's (1995:3) categorisation, the cases under investigation are thus defined as "instrumental case studies". This means that by studying these two cases it is hoped that the research can contribute to a more general understanding of urban climate change experiments. The qualitative case study approach is furthermore well suited with the larger interpretive framework of critical realism. As explored above, explanation is a key aim of critical realism (Easton 2010). Since qualitative case studies set out to comprehensively investigate, understand and explain a system, the approach is very compatible with the philosophical assumptions of critical realism.

3.3 Research Methods

The research methods were carefully selected to best answer the research questions. A mixed methods approach combining desktop research with semi-structured interviews was chosen. Throughout the research, both methods fed into each other as a feedback loop developed. The initial desktop research helped establish a crucial foundational understanding of the cases, which was used as a guiding outset for the interviews. The interviews subsequently fed back into the desktop research as new topics were uncovered and needed further examination. If later relevant these new topics were incorporated into future interview guides and further explored.

Desktop Research

Desktop research involved examining various types of non-statistical secondary data such as newspaper articles, municipal energy plans, the experiments' implementation plans, yearly reports, evaluations and meeting summaries from different stakeholders. A particularly important aspect of the desktop research was outlining the experiments' energy supply-related goals and aims. As mentioned in the introduction, CPH 2025 Climate Plan and ProjectZero are both based on a three-phase implementation strategy. ProjectZero's first phase ended in 2015, while the CPH 2025 Climate Plan's first phase will finish at the end of 2016. In both cases, an implementation plan was set out at the beginning of each implementation phase. From these plans an outline of the objectives was made. Through the interviews and further desk research, each objective has been followed up on. This provided a way to track progress, but also functioned as a tool for conversation in the interviews. The gathered information, both the objectives and their current status, are displayed in a table for each case. These tables are used in the case descriptions as an outset for analysis (see table 2 and 3 in chapter 5 and 6).

Stakeholder Interviews

A total of 13 stakeholder interviews were carried out during March, April and May 2016. Ten interviews were conducted through face-to-face meetings, two over the phone, and one through written correspondence. The verbal interviews lasted an hour on average. The stakeholders were mainly identified through desk research. The interviewees include individuals or institution representatives that have an interest or concern in one of the urban sustainability experiments. Developing knowledge of the cases through a diverse group of stakeholders helped build an understanding of the urban sustainability experiments that is based on multiple perspectives. Eight of the interviews were conducted with ProjectZero stakeholders, while five of the interviews were conducted with stakeholders from CPH 2025 Climate Plan. This unequal distribution of interviews is partly the result of greater difficulties experienced with recruiting in Copenhagen, particularly amongst municipal politicians. However, the case studies should not be considered two completely separate entities. Rather, the findings from one case study inform the other, and vice versa. See table 1 for an overview of stakeholder interviews.

Table 1: Overview of stakeholder interviews

Interviewee	**Position**	**Details**
Peter Rathje	Managing Director, ProjectZero	Interview: 11.03.16
Lene Sternsdorf	Municipal Climate Coordinator, Sonderborg	Interview: 16.03.16
Jørgen Abildgaard	Project Manager, CPH 2025 Climate Plan	Interview: 04.04.16
Peter Mikael K. Stærdahl	Managing Director, Gråsten District Heating	Interview: 11.04.16
Frode Sørensen	City Council Member, Head of Municipal Technical and Environmental Committee, Sonderborg Vice Chairman of the Board, ProjectZero A/S	Interview: 11.04.16
Erik Lauritzen	Mayor, Sonderborg Vice Chairman of the Board, ProjectZero Foundation.	Interview: 12.04.16
Lars B. Riemann	Managing Director, SONFOR Chairman of the Board, ProjectZero A/S	Interview: 14.04.16
Nicolas Bernhardi	Project Manager and Energy Planner, ProjectZero	Phone interview: 15.04.16
Mogens Elmvang	Chairman of the Board, Augustenborg District Heating	Interview: 15.04.16
Bo Asmus Kjelgaard	Former Mayor of Technical and Environmental Administration, Copenhagen	Interview: 18.04.16
Christina L. Rolandsen	Project Developer, HOFOR Wind	Interview: 29.04.16
Nina Holmboe	Energy Planner, HOFOR District Heating	Phone interview: 12.05.16
Frank Jensen	Lord Mayor, Copenhagen	Email

The interviews were semi-structured, which means that a thematic guide directed the conversations to some extent. The interview guide developed as knowledge about the case grew. Every stakeholder was given a different set of questions based on their individual role and relationship to the experiment in question. Despite the variation in interview guides the conversations focused on a number of similar topics. First, the interviews were a way to obtain more knowledge about specifically stated objectives and projects – how these were progressing and what obstacles and aids were experienced. Second, through the interviews it was possible to enquire into the relationship between the experiment and the specific place – what triggered the vision, why is the experiment vision important to the respective area. Third, the interviews allowed me to investigate the role of stakeholders – their motivation to engage and commit to the experiment. Fourth, through the interviews it was possible to examine the organisational set-up of the experiments – the advantages and disadvantages of being a municipal vs. a public-private partnership. Being semi-structured, the interviews were very conversation-like. The format enabled probing while simultaneously allowing the interviewees to challenge questions and themes, and to express their own views (Longhurst 2003). An interview guide example is found in Appendix I.

The interviewees were contacted through email or a phone call. Of the ten face-to-face interviews, nine were conducted at the interviewee's place of work and one was conducted at the interviewee's home address. Upon permission, the face-to-face interviews were recorded and subsequently transcribed. The phone interviews were not recorded, but instead documented through extensive note taking. All the interviews were carried out in Danish. The direct quotes in the thesis text are thus translations from the Danish transcripts or notes. During the interview, I was given verbal permission to use the names of interviewees in the thesis.

The interviews were analysed through thematic coding, shifting and sorting. The interviews were first coded with regards to the objectives and aims set out in the experiments. This enabled an initial overview of progress. During a second round of coding, all interview transcripts and notes were carefully read and openly coded. Any ideas or themes emerging from the material were noted. These codes were then categorised into events, themes and topics, that were subsequently used when reading the material again. Organising the material into codes made it possible to start seeing relationships between different codes and between the cases. It was an iterative process of slowly going from materials to a more abstract interpretation (Crang, 2005). During the analysis, ideas and findings were reflected back on the theory in order to better understand how the findings support previous research and offer alternative interpretations.

CHAPTER 4

ENERGY SUPPLY IN DENMARK

To provide a better understanding of the geographical context within which the cases exist, this chapter explores characteristics that define energy supply at the national scale. The chapter begins with an assessment of the major developments that characterise the Danish system of energy production and distribution, and subsequently introduces a relevant and current political debate on the topic. The chapter then moves on to discuss some of the main attributes that specifically distinguish the supply of electricity and heat in the Danish context.

4.1 A Tradition of Strong State Regulation

Danish energy supply has traditionally been subject to strong state regulation. Since the 1970s, policy measures particularly aim to achieve greater resilience and efficiency in the production and distribution of energy. These aims were initially driven by a need for greater energy security in the face of international oil shocks, but has since the 1990s onwards been increasingly fuelled by environmental and climate change concerns (Sperling *et al*. 2011). Broadly speaking, national strategic plans have encouraged four major changes. Related to energy production, national strategic plans have first supported a transition from oil to natural gas; however, in the face of climate change subsequent policies try to decrease dependency on fossil fuels. Second, a more diverse mix of energy sources has been achieved through encouraging the development of renewable energy. Third, greater thermal efficiency has been achieved through the promotion of combined heat and power (CHP) plants. Finally and mostly related to energy distribution, policy measures have increased efficiency through encouraging the growth of collective heating systems (Danish Energy Agency 2012).

In the 1970s, 90% of Denmark's energy supplies depended on imported oil. Consequently, the oil crises at the time hit the country hard (Chittum and Østergaard 2014). In 1977, the Danish government imposed taxes on oil to decrease dependency. When natural gas was discovered in Danish territories of the North Sea, use of this indigenous source of energy was encouraged as a complementary step to avoid oil dependency (Danish Energy Agency 2012). However, as concerns for climate change increased regulatory steps were taken to promote a transition towards more renewable energy sources. The promotion of renewable energy has played an important role in the long-term diversification of energy production in Denmark. Multiple political agreements have supported this process; most recently the 2012 Energy Agreement. The 2012 Energy Agreement was reached by a broad majority of the Danish Parliament. It states that the country's energy demand should be covered by 35% renewable energy in 2020, and that energy demand in 2050 should be entirely based on renewable sources. To achieve these goals the agreement sets out a number of initiatives and legislative changes (Danish Energy Agency N/A). Two of these changes are particularly relevant to the case analyses, and are therefore considered in the following.

First, the agreement introduced new legislation regarding oil and gas furnaces, which is particularly relevant to the case of ProjectZero. Following the energy agreement, buildings constructed after 2013 are not to install oil and gas furnaces, and from 2016 old furnaces cannot be replaced by new ones if the concerned building is located in an area that is covered by district heating or natural gas. Second, the 2012 Energy Agreement committed to ensuring a substantial development of additional wind power in Denmark, which the 2025 CPH Climate Plan is highly dependent on. The agreement states that wind capacity will be expanded through offshore state tenders at Kriegers Falk in the Baltic Sea and Horns Rev in the Eastern North Sea as well as through a near coast state tender for six wind farms located along the Danish coast (Energistyrelsen 2012; Danish Energy Agency 2016b).

Alongside the above-mentioned transitions in energy sources, Danish energy production has been characterised by an expansion of CHP systems resulting in improved thermal efficiency. CHP plants generate electricity and simultaneously make use of the ‘waste’ heat that is produced in the process (ADE 2016). In Denmark, the 1976 Electricity Supply Plan made it mandatory for all new power plants to reuse waste heat, and later tax incentives further encouraged the same development amongst existing power plants (Lipp 2007). The growth of CHP plants have occurred alongside the expansion of collective heating systems that distribute the waste heat to end users as either space or water heating. Following a 1979 Heat Supply Act municipalities were encouraged to build and expand district heating infrastructures. The act enabled municipalities to assign district heating to certain areas, which made it mandatory for households in those areas to connect to the collective infrastructure. Today, the Danish share of district heating and CHP market penetration are amongst the highest in the world and the country is internationally recognised for a very efficient energy production (LSE Cities 2014).

Current Political Debates

As the above illustrates, the system of taxes and tariffs in the Danish energy system is long standing and elaborate. Current political debates concern energy tariffs and the promotion of renewable energy. It makes sense to introduce the most recent discussions because they are directly related to the case analyses. By the end of 2016, Denmark must institute a new system of state support for renewable energy, since the European Commission determined that parts of the current system, the Public Service Obligation (PSO) tariff, breaches EU treaties. In Denmark the PSO is a tax on electricity consumption, the size of which is determined by the price of electricity. When the price of electricity goes up, the PSO goes down, and vice versa. PSO revenue is used to subside Danish production of renewable energy, particularly the wind industry (Blichert and Sparre 2016). When European electricity markets were liberalised in the 1990s previously established feed-in tariffs were withdrawn and European member states were able to instead introduce a PSO tariff (Meyer 2004). However, in 2014, the European Commission determined that parts of the Danish PSO tariff acts as an impediment to the free market of the EU because the levy applies to overseas companies that operate in Denmark, which are not however eligible for any of the subsidies in Denmark (Ritzau 2016). During May 2016, the Danish Government announced an abolishment of the PSO tariff altogether and suggested that the revenue generated from the tariff, which funds renewable energy, should be found elsewhere in the state budget. A few days later, the Government proposed to mitigate the costs arising from abolishing the PSO tariff through raising the bottom bracket tax (Søndergaard and Düwel 2016) and cancelling the near shore wind tenders, which were agreed to in the 2012 Energy Agreement (Nielsen 2016). The situation remains unsettled, but it is later suggested in the case analyses that this political change of heart could potentially have a large impact on particularly Copenhagen's carbon vision.

4.2 Electricity Supply

This section introduces some of the key characteristics of Danish power generation and it specifically focuses on the challenges that Denmark faces with regards to introducing a greater proportion of wind power. In both cases, the goals related to electricity are strictly related to production; changing the sources. However, as this brief description shows, the Danish power infrastructure is also facing large changes in terms of distribution and transition and the national perspective therefore provides an important perspective to keep in mind when reflecting on the urban experiments.

In Denmark, electricity is mainly brought to end-users through a national electricity grid, which means that most users get their electricity through a collective system. Electricity is generated at multiple sites, most of which feed into the national grid[1]. The electricity grid consists of a combined transmission and distribution network. Simply put, the transmission network consists of lines that move high-voltage electric energy from the point of production to substations where voltage levels are lowered. The distribution network then moves the lower-voltage electricity from the substation to the end-users. The Danish electricity grid is also linked through transmission networks to neighbouring countries including Germany, Norway and Sweden (Nygaard *et al*. 2014).

In both cases, the goals related to electricity are solely related to production and the overarching aim is to transition from fossil fuels to renewable sources. This aim is mirrored in national policies where as mentioned the goal is to achieve 100% carbon neutrality by 2050. To achieve this, onshore and offshore wind turbines are expected to

[1] It is possible for households or companies that own for instance a private wind turbine to bypass the collective electricity grid and instead use the electricity that the turbine produces directly. Depending on the size of the plant, the generated electricity is charged with a tariff.

provide the majority of electricity. For decades Denmark has pioneered with regards to wind power penetration, however, the aims of further increasing the proportion of wind power poses a number of challenges related to national (and international) transmission and distribution networks. Since wind is a fluctuating energy source, systems with a high reliance on wind power experience times of abundant supply, and periods with insufficient supplies. A flexible network of transmission and distribution is key to ensure the security of electricity supply as well as attain the best value from renewable energy production (Meibom *et al*. 2013).

One way of attaining flexibility is through international trade. Currently, when wind power production peaks in Denmark it is difficult to export the excess supply and prices consequently fall or even become negative, which means that wind producers experience economic loss. To overcome this, Denmark is looking to increase international interconnections to achieve a higher flexibility. However, developments like these require large investments in new infrastructure networks. Creating a better integration between domestic energy systems, such as the electricity, transportation and heating systems can also contribute to a better utilisation of electricity in periods of excess production. This integration could for instance be achieved through an increase in the use of electric vehicles, whereby batteries store excess energy and thus integrate the energy systems of electricity and transportation. Better integration can also be achieved by linking the heating and electricity networks through heat pumps in collective heating systems. But again, these are also potential solutions that require large investments (Xu *et al*. 2009). These examples start to illustrate that achieving a carbon neutral power supply goes beyond changing the source of production. The experiment goals should be viewed in light of these large national infrastructural developments.

4.3 Heat Supply

In this section key characteristics of Danish heat supply are introduced. First, the section provides a basic presentation of the infrastructure, and then considers how the Danish system is influenced by a tradition of strong local planning as well as an overarching non-profit principle. The section finally introduced current discussions related specifically to the production of heat.

Unlike electricity, the Danish system of heat supply is more local and distribution can take various forms. The majority of Danish households are connected to collective distribution systems such as a district heating system, while individual furnaces heat approximately one-third of households (Energistyrelsen N/A). As the case analyses will show, the City of Copenhagen is almost entirely supplied with district heating and consequently the city’s carbon vision is less concerned with issues of distribution and more concerned with issues relating to production. In Sonderborg the district heating coverage is a lot lower, and the city’s carbon vision is therefore concerned with developing the city's distributional system, as well as ensuring carbon neutral production at both the collective and individual scale.

Although the Danish government determines overall energy frameworks and tariffs, local heat planning, regarding both production and distribution, has traditionally been strong in the Danish context. The before mentioned 1979 Heat Supply Act not only encouraged the expansion of district heating, but also required municipalities to carry out local heat plans that assess supply and demand in the local area. The plans became an instrument through which municipal authorities were given planning and provision responsibility (Chittum and Østergaard 2014). Today municipalities remain responsible for "preparing and updating municipal heating plans and approving projects", which means that final decisions concerning either production or distribution of heat are determined by the local authorities (Danish Energy Agency 2015:15).

Heat supply in Denmark is also based on a non-profit principle with cost based pricing. This means that the supplier can neither generate income nor subsidise prices. Annual benchmarking between suppliers across the country is carried out to protect consumers in terms of the price of heating (Danish Energy Agency 2015). Across Denmark district heating is supplied by municipally owned utility companies or cooperatives, which are locally regulated by municipalities. When deciding to approve or refuse heat proposals, municipalities are required by law to consider socio-economic costs and benefits. This means that "the full societal costs of energy projects are calculated, and that only projects showing the best net benefit to society are prioritized" (Chittum and Østergaard 2014:467). Reducing fossil fuel dependency is one aspect that is considered a benefit in this analysis. The combination of the non-profit principle and the socio-economic cost-benefit analysis leaves suppliers in quite a complex situation. If they want to carry out a new project they have to on the one hand ensure an internal business case so that consumers do not suddenly experience an increase in prices, but on the other hand projects are only approved if they demonstrate a high value in the socio-economic cost benefit analysis. The system is thus set up to achieve two main things: first, keep heat supply at a price as low as possible for the consumer, and second, ensure that infrastructural developments are aligned with broader visions of society, mitigating climate change being key in contemporary society (Chittum and Østergaard 2014)

Although municipalities are responsible for approving new projects, they cannot force suppliers to carry out new schemes. For instance, in the City of Copenhagen, HOFOR District Heating, a municipal utility company, supplies heat. The municipality of Copenhagen owns all shares in HOFOR District Heating and as owner can influence the company's decisions. They cannot however force HOFOR District Heating to invest in projects that the company deem unprofitable, even though the municipality might politically prioritise these projects. The same is of course true in Sonderborg, where heating is supplied by four cooperatives and SONFOR, a municipal utility company

(Hannibal *et al*. 2010). As the case analyses will demonstrate heat planning is both an important and difficult process when trying to fundamentally alter local energy production.

The final point developed here relates to current developments in the sources of heat production. Since the 1990s Danish heat production has been characterised by a steep increase in biomass, a development that is also reflected in both ProjectZero and CPH 2025 Climate Plan. The development is widely debated at both the scale of the experiments and more widely on a national scale. Opponents of the increasing use of biomass critique the assumed sustainability of the practice and question whether Denmark in the long run will be able to produce enough biomass to sustain increasing demands (Danmarks Naturfredningsforening N/A; CONCITO 2013). Proponents argue that biomass is a good interim technology and if combined with wind and solar power remains a more sustainable solution than systems based on coal and natural gas. Proponents moreover insist that Denmark should focus on developing an international certification scheme to ensure that imported biomass is sustainable (Dansk Energi 2013). Intertwined with the discussions for and against biomass is a growing narrative, which calls for a broader technological shift. Multiple actors are arguing that instead of boosting incineration, the system of taxes should encourage electrification in heat production through for instance an increasing use of heat pumps (CTR *et al*. 2014; Dansk Energi 2014; Dansk Fjernvarme 2015; Klimarådet 2015).

CHAPTER 5

THE CASE OF PROJECTZERO

ProjectZero is the vision of achieving carbon neutrality and creating green growth in the municipality of Sonderborg by 2029 (ProjectZero 2011). Futura Syd, a regional think-tank formulated the vision. Concern about local socio-economic decline was a particularly important catalyser for the initiative. The vision was institutionalised in 2007 when ProjectZero Company and the ProjectZero Foundation were set up to realise the vision. ProjectZero is a public-private partnership between the municipality of Sonderborg and the Danfoss Foundation, the Nordea Foundation, Syd Energi (SE) and DONG Energy. The University of Southern Denmark (SDU) is actively involved in the initiative and in 2014 SONFOR also officially joined the partnership. ProjectZero Company is owned by the ProjectZero Foundation, which helps fund, the company's daily activities (ProjectZero N/A). The figure below illustrates the organisational and funding structure of ProjectZero.

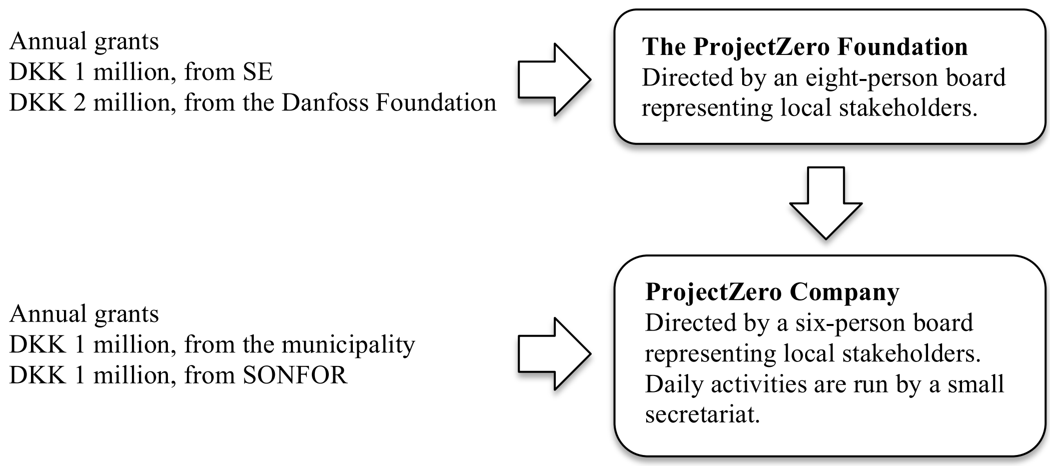

Figure 2: ProjectZero's organisational and funding structure (Peter Rathje, interview)

ProjectZero is well anchored in the local environment. It has been adapted as one of three municipal visions, so-called lighthouse projects, which represent longer-term aspirations for the area (Sonderborg Kommune 2016). As figure 1 shows, ProjectZero is economically supported by local organisations, both public and private. The two ProjectZero boards are important platforms where stakeholders share knowledge to ensure a strong integration of stakeholder interests. Three of the interviewees in this project simultaneously occupy positions in one of ProjectZero's two boards and hold influential positions in other local organisations. Erik Lauritzen is mayor in Sonderborg and vice-chairman in the ProjectZero Foundation. Frode Sørensen is head of the municipal technical and environmental committee and vice-chairman in ProjectZero Company. Lars Riemann is the managing director at SONFOR and chairman in ProjectZero Company. This cross-integration is fundamental to the vision, as

ProjectZero aims to engage the entire Sonderborg area. Through stakeholder participation, the project wants to create a green platform where citizens, public organisations and the private sector build competencies that enable a transition towards carbon neutrality. In addition to the carbon agenda, ProjectZero aims to achieve sustainable economic growth as well as maintain and further develop employment opportunities, particularly through green job creation in knowledge intensive sectors (ProjectZero 2011).

The interviewees are asked to reflect on ProjectZero's status as a public-private partnership. There is a general agreement that the setup gives ProjectZero a great deal of flexibility. Lene Sternsdorf from the municipality of Sonderborg argues that the public-private constellation enables ProjectZero to circumvent legislation that the municipality must abide by: "we can hardly do anything before it is considered distortive to competition, whereas ProjectZero can legally highlight and work with specific companies". Erik Lauritzen also explains that the commitment from organisations beyond the municipality is crucial for the vision: "the public-private partnership has enabled organisations to economically commit to the vision, and it has brought knowledge and expertise together from both the public and private sector". According to Lars Riemann, one of the main challenges of the constellation is that the private sector partners are so aware of investment returns. This was particularly difficult when ProjectZero was founded and a lot of resources were used on documentation and building networks and knowledge. Activities that showed limited concrete progress.

A secretariat, consisting of 4-5 full-time employees, is responsible for realising the vision and is thus the practical facilitator of the transition to carbon neutrality. The secretariat is in charge of carbon monitoring and projects mainly related to citizen participation. Peter Rathje, managing director at ProjectZero, explains that the secretariat "coordinate projects among stakeholders and follow up on these initiatives to make sure that things get done". As such the secretariat works to catalyse and communicate ProjectZero's vision, to both local stakeholders, in order to encourage participation, but also to national and international audiences as a way to attract attention to the project and the Sonderborg area. Lene Sternsdorf, climate coordinator at the municipality of Sonderborg, explains that ProjectZero on one hand "coordinates initiatives and gathers local interest and energy in one place", and on the other hand connects Sonderborg with the world around: "they have built a very big network with contacts around the world, which further endorses the project".

Utilising broader networks is an important strategy for ProjectZero. Sonderborg is a relatively small municipality with limited influence on national and international scale. Through collaboration with other cities and projects Peter Rathje explains that ProjectZero can gain bargaining power to challenge political obstacles that hinder the vision. He asserts:

If things are not moving fast enough in the networks that we are part of, then we have to influence and become part of broader networks. People wonder why we spend resources on projects in China. It's because it helps move the vision forward, carbon neutrality is made more legitimate when more people and projects work towards it [...] Similarly, the EU seems to have pretty much stalled with regards to climate issues, but this morning I read that the US has put forward a more ambitious climate plan. We can only applaud this and hope it will put pressure on the EU, which again will put pressure on Denmark to create better framework conditions for projects like ours.

The vision of carbon neutrality in Sonderborg encompasses all energy-related consumption within the municipality, including road transport, but excluding rail, sea and air transport. When calculating emissions, carbon emissions from imported products are not added while carbon emissions from exported products are not subtracted (ProjectZero 2009a). In 2009, ProjectZero published a master plan, which sets out the overarching strategy for achieving carbon neutral growth by 2029. A step-wise implementation of the master plan is set out in individual roadmap documents. The first, 'Roadmap 2010-15', was published in 2009, and the second, 'Roadmap 2020', was published in 2014. The analysis of this case is based on implementation goals set out in 'Roadmap 2010-15'. The goals in the roadmap are divided into five overarching themes: heating, electricity, lighting and electric appliances, manufacturing processes and transportation. Of those five themes, two include goals that are particularly related to energy supply, these are: heating and electricity.[2] These specific goals will be returned to in the case analysis. However, before discussing the case analysis we will further explore how ProjectZero is embedded in a broader geographical context.

5.1 Geographical Context: A Broader Strategy of Survival

The ProjectZero vision was created against the backdrop of reports, which stated that areas such as Sonderborg would face future socio-economic decline (Peter Rathje; Lene Sterndorf, interviews). It is thus argued, that ProjectZero should be understood against a larger narrative of need for local survival. In line with the theoretical understanding that geographical context matters, this section sets out to introduce the Sonderborg area and to explore how ProjectZero is locally embedded.

The geographical and political-administrative entity that is referred to as the municipality of Sonderborg is actually a rather recent constellation. Following national structural reform in 2007, seven municipalities (Augustenborg, Broager, Graasten, Nordborg, Sonderborg, Sundeved and Sydals) were merged into what is today the

[2] The heating and electricity themes include goals that are related to both energy consumption (e.g. retrofitting houses to decrease consumption of heat) and energy supply (e.g. changing the source of heating from a system based on fossil fuels to one based on biomass). The analysis is only based on the goals relating to energy production.

municipality of Sonderborg (Schønau 2005). As displayed in figure 2, the municipality consists of the island of Als and a small part of Jutland. The latest census states that the municipal population consists of 74,737 people (Danmarks Statistik 2016). The municipality is characterised by a diverse geography with urban, semi-urban and rural areas. Sonderborg and Nordborg are the largest urban areas where approximately 35% and 10% of the population reside, respectively. Twelve per cent of the population live in rural areas, defined as villages with less than 200 inhabitants. The remaining population lives in smaller cities with between 1,000 and 5,000 inhabitants (ProjectZero 2009a). Demographic changes are a matter of concern in the municipality. Since 2010 the population has decreased by 2.2%. During that same five year-period, the population in Denmark increased by 3.1% (Danmarks Statistik 2016[3]). The population is aging because younger inhabitants are leaving the area. As a result the economically active population is decreasing and the area is struggling to make up for the out-migration (Sonderborg Kommune 2014).

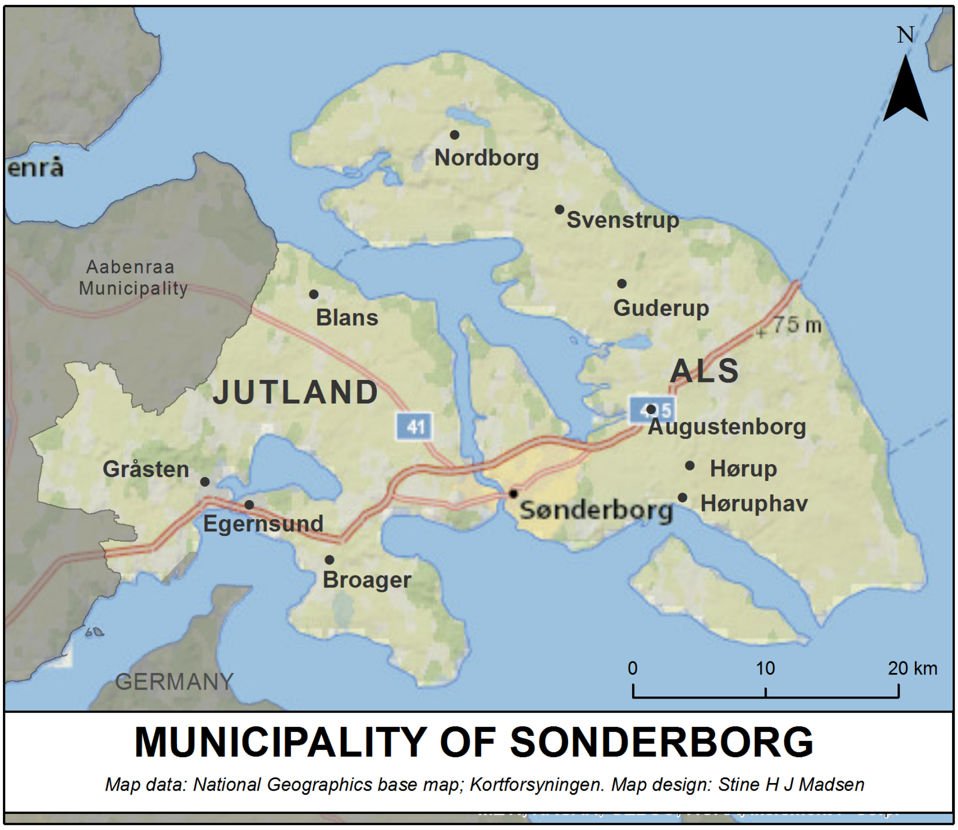

Figure 3: Map of the municipality of Sonderborg

Sonderborg's economic landscape is particularly characterised by agricultural production and strong competences in high- and clean-tech industries. Agricultural

[3] The population change is calculated on the basis of statistics from the first quarter in 2010 and the first quarter in 2016

activities are focused on multiple aspects of pork production, both breeding and slaughtering. In terms of the high- and clean-tech industries, Danfoss, a global producer of fluid handling components and valves, has since its establishment in the 1930s had an important influence on the area's economic landscape. The company has created a basis for the establishment of smaller supply companies within related industries and has actively been engaged in knowledge sharing activities. As a result, the Sonderborg area has developed particular skills within the manufacturing of products that increase energy efficiency. Multiple companies in the area are specifically involved in the production of renewable energy technologies (e.g. district heating, solar power, heat pumps) (ProjectZero 2009a). Despite the strong presence of this high-tech cluster, the area is struggling to attract qualified labour, and the above-mentioned demographic development is a key source of concern (Region Syddanmark 2015).

The ProjectZero vision of green growth and carbon neutrality departs from the idea that the area needs to capitalise on the local knowledge base and industrial make-up in order to address the demographic developments and the socio-economic challenges. This is well articulated by Sonderborg's mayor, Erik Lauritzen:

> *The carbon vision really makes sense in Sonderborg because we have companies that work within the field. So while we follow some sort of idealism to be more sustainable we are also creating a context for growth and new employment opportunities […] ProjectZero is not philanthropy, but an effective way of supporting production amongst local high-tech companies like Danfoss and Linak.*

A key aspect of ProjectZero is transforming the Sonderborg area into a showcase, the so-called ZEROcity Demonstratorium, for new green technologies, many of which are produced by companies in the area (ProjectZero 2009a). While showcasing a local transition, the area is also creating a real-life display of technological solutions. Lars Riemann, head of SONFOR, explains this with regards to district heating:

> *We spend a lot of effort conveying that this is also a growth vision. All the developments that we are making to our district-heating network helps create a unique demonstratorium. Within a radius of 20 kilometres we can take business tourists to see all kinds of technical solutions for heat production… a waste inclination plant, wood chip biomass plants, a geothermal well, solar heat plants, a biogas plant, a straw boiler, heat pumps, and so on […] this makes it possible for local companies to sell their products through the area, which we hope will bring more prosperity.*

Growth and climate ambitions are combined in ProjectZero. The vision is one of creating carbon neutral growth, but it is also an important opportunity to address broader place specific challenges.

5.2 Energy Supply in Sonderborg

Transitioning to an intelligent energy system based on renewable sources is key to achieve the ProjectZero vision. In 2007, when ProjectZero was established, electricity in the municipality was generated through CHP plants (53% of total production, burning mostly natural gas and waste), onshore wind power (4% of total production) and imports from outside the municipality (43% of total production). Approximately 34% of heat demand was generated by collective sources (district heating, again based mainly on natural gas and waste), while the majority of demand was met by individual sources (mostly oil and gas furnaces, electric heating and a small amount of heat pumps and biomass furnaces) (ProjectZero 2009a:31,57).

ProjectZero's goal is to base electricity and heat production on carbon neutral fuels including wind power, biomass, biogas, geothermal power, solar power and waste incineration. In addition to making a transition in energy production, ProjectZero also aims to develop the municipality's system of heat distribution by expanding the collective heating infrastructure. Expanding the collective heating infrastructure is believed to increase energy efficiency. It is the long-term goal that district heating by 2029 supplies 62% of the total heat demand. In areas were district heating is not available, due to low population densities, individual heating solutions should be converted to green alternatives such as heat pumps, biomass furnaces, solar panels with water accumulators and immersion heaters (ProjectZero 2009a).

These overarching goals are broken down over time in implementation plans. The specific goals relating to energy supply in the first implementation plan, 'Roadmap 2010-15', are outlined in table 2 below. The table also includes a short description of the current status for each goal. The remaining part of this section departs from table 2 to further explore the extent to which these goals have been met and uncover reasons why some of them have not been met.

Heating

More than half of the goals outlined in table 2 are directly related to changing the municipality's distributional heating infrastructure. The overarching aim is to expand district heating and ensure that buildings located within the district heating networks are connected to the collective heating infrastructure. The district heating cooperatives in Sonderborg and Graasten have expanded their network, which contributes to the goal, however Peter Mikael Stærdahl from the cooperative in Graasten reports that they are struggling to get buildings connected to the network.

Table 2: Energy supply aims in ProjectZero's first implementation phase (the goals are adapted from ProjectZero (2009b))

Stated goals	**Current status**	**Source**
Expand existing district heating networks in Graasten, Broager, Sonderborg, Augustenborg and Nordborg to include peripheral areas that today are supplied with natural gas.	**Partly completed:** This is a continued aim. Some improvements have been made as a result of expansions: Graasten District Heating cooperative have expanded with a transition pipe to Egernsund, Sonderborg District Heating cooperative have expanded the network to areas in Horuphav and Horup.	Municipality of Sonderborg (2014) ProjectZero (2013a)
50 % of all buildings with an oil or gas furnace that are located within the expanded district heating networks should be connected to the district heating network before 2015.	**Unknown:** It has not been possible to assess this goal in a numerical way, since data has been difficult to assess. On a qualitative note, it can be said that the expansion in parts of the district heating network in Graasten and Sonderborg has contributed to the goal, while the rejection of the transmission pipe between Sonderborg and Nordborg has been a hinder.	Nicolas Bernhardi (Interview) Peter Mikael Stærdahl (Interview)
Establish transmission pipe to connect district heating networks in Sonderborg, Augustenborg and Nordborg.	**Not completed:** The district heating cooperatives in Augustenborg and Sonderborg turned down this proposal. SONFOR is now in charge of a new proposal that is to expand the district heating network in areas around Nordborg.	Lars Riemann (Interview)
Connect Danfoss to the district heating network.	**Not completed:** This was supposed to have happened with the transmission pipe, the goal however, is also included in the new proposal put forward by SONFOR.	Lars Riemann (Interview)
Establish new district heating networks in Guderup, Svenstrup and Horuphav.	**Partly completed:** Sonderborg District Heating Cooperative have expanded the network to Horuphav. Establishing new district heating networks in Guderup and Svenstrup is also included in the new proposal by SONFOR.	Rambøll (2016) Sonderborg Fjernvarme (2015)

Table 2: continued

Stated goals	Current status	Source
50 % of all buildings with an oil or gas furnace that are located outside the expanded district heating networks (countryside districts) should change heating systems before 2015.	**Unknown:** The 2015 municipal Heating Plan states that there is only about 1000 oil furnaces left in areas outside district heating networks. However, proper data from the outset does not exist, and it is therefore impossible to say whether reductions equal 50%. Similar problems exist with regards to data on gas furnaces.	Nicolas Bernhardi (Interview) PlanEnergi (2015)
Change to alternative heating in all buildings with electric heating systems.	**Not completed:** In the latest Heating Plan it is clear that many seasonal households still rely on electric heating.	Nicolas Bernhardi (Interview) PlanEnergi (2015)
Establish solar heating plant in Broager.	**Completed:** A 10000m^2 solar plant was established in 2009.	PlanEnergi (2015)
Establish geothermal power plant in Sonderborg.	**Completed:** A geothermal plant was established in 2013.	Sonderborg Fjernvarme (2015)
Establish biogas plant near Graasten.	**Not completed:** In October 2015, it was announced that a biogas plant is to be built in Blans, near Graasten. The plant is the result of collaboration between the municipality, ProjectZero, NGF Nature Energy, SONFOR and local farmers. It is expected to be up and running in 2018.	Energy Supply (2015) ProjectZero (2015)
Establish on-shore wind capacity of 10MW before 2015.	**Partly completed:** Two wind turbines were put up in 2013, providing a total of 4.6 MW. Other on-shore wind plans have been put on hold.	ProjectZero (2013b) Peter Rathje (Interview)

He explains, that since there is no mandatory connection requirement in the municipality of Sonderborg, the cooperatives rely on homeowners' willingness to invest and their wish to connect to the network. The cost of connecting varies from building to building, but the price in the municipality is usually about DKK 40-60000. Peter Mikael Stærdahl argues that the current price of natural gas is one of the main reasons why the cooperative is struggling to achieve a higher connection rate.

> *Natural gas is so cheap today, which makes it difficult for me to sell district heating to new customers. The economic incentive to change is small, while the payback period on the household investment is much longer today than it was a few years ago.*

Peter Mikael Stærdahl expresses particular frustration with the fact that a number of the municipality's buildings in the area have not been connected to the new network: "it feels like they're making fun of us. They know that our accounting liquidity is under pressure because we need more connections. They should be setting a better example".
When asked about the issue, Erik Lauritzen, mayor in Sonderborg, said he knew little about the exact case, but believed that the additional costs of connecting had not been budgeted for, perhaps because other expenses had been prioritised. He concluded: "these are the dilemmas we're faced with all the time, prioritising is tough".

In 'Roadmap 2010-15', the establishment of a transition pipe between Sonderborg and Nordborg is a key goal related to the expansion of district heating. The pipe would make it possible to establish district heating networks in smaller communities that fall along the pipe such as Guderup and Svenstrup, which do not have district heating today. Similarly, larger manufacturing companies along the pipe could be connected including Linak and Danfoss (ProjectZero 2009b). The project was approved by the city council, but fell through because the utility cooperatives in Sonderborg and Augustenborg pulled out of the project. Both cooperatives argued that building and running the pipe would be economically disadvantageous to their consumers (Augustenborg Fjernvarme 2014; Sonderborg Fjernvarme 2014). Mogens Elmvang from Augustenborg's cooperative explain:

> *The municipality and ProjectZero talk socio-economics, that is tons of CO_2, I am talking company economics, that's how much people pay for their heating. As chairman of the board my loyalty is with the latter. From the perspective of company economics we couldn't support the pipe.*

Following the rejection of the transmission pipe proposal, a new plan has been put forward by SONFOR. It will not initially connect the networks in Nordborg, Augustenborg and Sonderborg, but it will extend the network in and around Nordborg (Rambøll 2016).

In an attempt to avoid rejection of future proposals the municipality of Sonderborg has subsequently initiated a more inclusive process of strategic heat planning. When the latest heat plan was drafted in 2015, the utility cooperatives were invited to actively engage in the planning process. Previously, the municipality had carried out the planning largely on their own. Across interviews, this new process was praised and stakeholders argued that it improved communication and collaboration between actors. The example of the transmission pipe quite nicely illustrates some of the mechanisms that underpin municipal heat planning, which were outlines in section 4. Changing the infrastructure requires that the municipality on the one hand considers the project socio-economically beneficial, while the utility supplier on the other hand is convinced about the project's internal business case.

Despite the improved collaboration between the municipality and the utility companies, Peter Mikael Stærdahl from Gråsten District Heating made me aware of a current legal dispute, which highlights further insights about political priorities in the municipality. The legal dispute exists between the municipality and the utility cooperatives in Sonderborg and Graasten. Since the cooperatives rely on a non-profit principle, new investments are financed through loans, which the municipality provides security for. In 2010 and 2011, the cooperatives in Sonderborg and Graasten borrowed a total of DKK 450 million to realise projects in accordance with the municipal heating plan. They extended district heating networks, built a geothermal plant, biomass plants, and a solar plant. The municipality did not initially require a commission when providing the security, however, one year after the last loan security was approved, the city council agreed to charge an annual one per cent commission on the loans, retrospectively (Retten i Søndeborg 2014). The cooperatives filed a lawsuit against the municipality, arguing that they could not impose the charge retrospectively, especially since it was previously put in writing that no charge was needed. The cooperatives won the case in the district court, but lost in the high court. They are now waiting to see whether the case will be trialled in the Supreme Court. Peter Mikael Stærdahl remarks: "I don't think it is a fair way to treat team players. We are actively contributing to the heat plan and the reward we get from the municipality is a huge bill". When asked to comment on the case, Frode Sørensen, local politician, argues that the decision was pragmatic in nature:

> *It is politics in its purest form. I can't remember exactly how much the municipality profited from this, but it was surely an amount, which enabled us to reduce the price of childcare in some institutions. That's how we operate politically.*

Sonderborg's mayor advances a similar argument. He states that although the municipality is behind the ProjectZero vision, the city council is constantly faced with dilemmas of how to prioritise municipal spending – the climate agenda does not always end out on top in those discussions. With particular regards to the dispute, he emphasises that external actors influence the municipality, too:

> *I'm actually not very pleased with the way this has been handled, but we have agreed to keep our stand in solidarity with other municipalities [...] we are under pressure from other municipalities as well as the Organisation of Danish Municipalities, who are afraid that if we give in, then in similar conflicts will arise around the country.*

Moving on from the dispute and goals related to collective heating, table 2 also includes goals that address individual heating solutions. Some areas in the municipality of Sonderborg are so sparsely populated that district heating is not considered an opportunity. Instead carbon neutral individual heating solutions are needed. A main objective is replacing gas and oil furnaces with green alternatives. The aim in 'Roadmap 2010-2015' is to halve the number of fossil based furnaces. It is not possible to say whether this goal has been achieved since accurate data on the issue was never produced when the goal was set. Despite the data challenges interesting insights on the topic came forth in the interviews. Peter Rathje explains that ProjectZero has recently tried to map the distribution of gas and oil furnaces in the municipality in order to keep better track of progress. As part of the process ProjectZero carried out a demographic analysis, which reveals that a great majority of homeowners that rely on oil and gas furnaces are elderly. A number of the interviewees suggest that the aging demographic makes the transition more difficult. Frode Sørensen remarks:

> *It is my experience that the elder generation tend to say; 'it's always been like this, why change'. Many are probably thinking that they will only be living there the next ten years or so, and therefore might not really benefit from making those changes. You always have to think about the payback period and such.*

As mentioned previously, Sonderborg is characterised by an aging demographic and this therefore points towards a very place specific challenge. In a similar vein, the municipality's housing stock is also cause for a place specific challenge. The municipality of Sonderborg is home to a lot of vacation properties, many of which are not connected to the collective heating systems. Nicolas Bernhardi, project manager at ProjectZero, explains that electric heaters are a particularly popular source of heating in many vacation homes, however they are very energy intensive. 'Roadmap 2010-15' aims to install alternative heating in properties that rely on electricity. Unfortunately, the goal is far from achieved mainly because many of the concerned properties are seasonal homes. Nicolas Bernhardi contends:

> *The savings you make from investing in a vacation home are lower and thus the incentive is smaller. This is particularly the case with electric heating. It is very costly to go from electric heaters, which are so easy to set up, to a more advanced system, because the infrastructure does not exist. It is a huge investment to get radiators and everything. People just don't find it worthwhile in homes they only use for part of the year.*

Introducing Renewable Energy Sources

In addition to changing the heat distribution infrastructure, the goals in 'Roadmap 2010-15' are also concerned with changing the energy production through the introduction of more renewable energy sources. In accordance with the goals, Broager District Heating Cooperative established a solar plant to supply their collective network, and in 2013, Sonderborg District Heating Cooperative opened a geothermal plant. Since its launch in 2013 the geothermal plant has experienced technical difficulties and is only operating at 25% of the expected effect. The technical difficulties are related to the underground water temperature, which is not as high as expected. For unclear reasons the underground geothermal injection well also blocks on occasion (Sonderborg Fjernvame 2015). The goal of setting up a biogas plant near Graasten has not been achieved, but an agreement to build the plant was made official in 2015. The plant is to be located in close proximity to a large slaughterhouse in Blans and its expected to be finished in 2018.

Although not planned for in the roadmap, it is worth mentioning that Gråsten District Heating Cooperative made the transition from a regular natural gas plant to a carbon neutral production during the time of the first implementation plan. The cooperative established a 19,000m^2 solar plant and invested in a straw boiler. Managing director, Peter Mikael Stærdahl explains that the shift was possible mainly due to economic circumstances. At the time natural gas prices were very high and thus renewable sources of enegy were a lucrative choice. Augustenborg District Heating Cooperative has similarly tried to introduce new sources for their base load production. Chairman of the cooperative, Mogens Elmvang, remarks that they are looking into installing a big heat pump, which uses electricity to produce heat. However, he explains that the taxation system disadvantages the use of heat pumps, which makes it very difficult to install one without economic loss and a resulting increase in heating prices. He insists that the idea is still on the table, but progress is slow due to national legislation.

'Roadmap 2010-15' finally includes a goal of increasing the onshore wind capacity with 10MW before 2015. In 2013, two turbines with a combined effect of 4.6 MW were put up on a private field in the southern part of Als, but all other planned projects have been put on hold and so the goal has not been achieved. Onshore projects in the municipality have been stalled due to both public resistance and changing political priorities. The issue of wind power peaked a few months before local elections in 2013. At the time local resistance to onshore wind turbines increased and the Social Democrats decided to pull their support for further environmental assessments, the next necessary step in the process of putting up more wind turbines. The ProjectZero vision has enjoyed full support from all parties in the city council and the Social Democrats insisted that they continued to support ProjectZero, but they called for the wind process to be put on standby for five years, as local resistance was too great and knowledge of potential health related consequences, too small (Nielsen 2013). The official explanation is that politicians await a national report from the Danish Cancer Society, which investigates correlations between health risks and noise from wind turbines (Lene Sternsdorf, interview). However, Frode Sørensen, a member of the Social Democrats, insists that the decision was a "political manoeuvre". An opinion shared by Lars Riemann, who contends: "the issue of wind turbines came up during the local election. From where I stand, it became a bit of a hot potato for the politicians and so they decided to put the issue on ice". Erik Lauritzen, also a Social Democrat, emphasises that the resistance to onshore wind power could jeopardise ProjectZero more broadly, which arguably justified the change of heart:

> *If the resistance towards wind turbines means that the general support for ProjectZero starts to crumble, then I think the price to pay is too high [...] I don't think we, as a city council, should push a project through when the resistance is so pronounced.*

No matter the underlying reasons, local resistance to onshore wind power and the subsequent change of political opinion are obstacles for achieving the roadmap goal.

To briefly sum up the case of ProjectZero it is noticeable that the urban sustainability experiment has been able to build a narrative that speaks convincingly to some of the geographical challenges and opportunities in the area. This has helped mobilise local stakeholders and secured economic funding from both public and private institutions. Despite commitment to the vision, the case also reveals political inconsistencies that challenge the energy transition. However, issues of political will and priorities are nuanced by the fact that the municipality is impacted by political structures outside the municipality such as the Organisation of Danish Municipality, which pressured local politicians regarding the commission on loan securities provided for the district heating cooperatives. The case also suggested that place specific characteristics, demography and the housing stock, hinders the urban sustainability experiment. Finally, national legislation impacts the experiment in numerous ways. For instance, although heat planning takes place at the scale of the municipality, changing the infrastructure is very dependent on nationally decided taxes and tariffs. Subsidies support the expansion of biomass, while heat pumps in the district heating networks are disadvantaged. This starts to question the autonomy that the municipality actually exercises, which in turn impacts the municipality's ability to make a transition to energy supplies.

CHAPTER 6

THE CASE OF THE CPH 2025 CLIMATE PLAN

The CPH 2025 Climate Plan is the vision of making the City of Copenhagen the world's first carbon neutral capital by 2025. The aim of carbon neutrality is envisioned alongside the objective of boosting green growth and increasing the quality of life amongst local residents. The climate plan was adopted in 2009 in response to the Copenhagen Climate Change Conference (COP15) the same year. The city council unanimously approved the strategy and further decided that the ambition should be followed up with an implementation plan after the climate conference. Building on the city's pre-existing green image, Copenhagen is to show the world how large metropolitan areas can transition to low carbon solutions (City of Copenhagen 2012).

The CPH 2025 Climate Plan is from the outset a political vision. The political responsibility of the plan lies with the mayor of the Technical and Environmental Administration, but the plan is anchored across administrations in the municipality including the Financial Administration and the Culture and Leisure Administration. A secretariat comprising of 10-12 employees is responsible for realising the implementation plan. The secretariat is part of the municipality's climate unit that is situated in the municipality's Technical and Environmental Administration (Københavns Kommune N/A). The role of the secretariat in Copenhagen is very similar to that in Sonderborg. Jørgen Abildgaard, project manager of the secretariat, explains that they keep track of the implementation plan and coordinate projects. They moreover maintain networks with similar projects in Denmark and abroad to share knowledge and experiences. Although the climate plan is a municipal undertaking, Jørgen Abildgaard emphasises that an important role of the secretariat is to speak on behalf of the vision if political priorities start to diverge from the goal: "we have to keep them [the politicians] committed to the goal and blow the whistle if things are going wrong".

Although the Copenhagen climate vision is formally a municipal undertaking, the attempted transition intends to create a joint collaboration between citizens, politicians, public utility companies, the private sector and knowledge institutions (City of Copenhagen 2012). Bo Asmus Kjeldgaard explains that multiple stakeholders were involved in the process of drafting the plan and even defining the vision: "I think the whole idea of creating a carbon vision for Copenhagen came from Rambøll [a Nordic consulting engineering group]". The private sector and knowledge institutions were invited for round table discussions to develop ideas and Jørgen Abildgaard explains that this involvement has recently been further formalised through the establishment of a climate advisory board where Danish climate experts meet 4-5 times a year with the mayor of the Technical and Environmental administration to discuss Copenhagen's challenges and future initiatives.

The need for stakeholder involvement is also emphasised in terms of the funding of the carbon vision. Jørgen Abildgaard explains that the secretariat is funded by the municipality, which has also committed to funding a number of specific climate projects including retrofitting of municipal buildings, construction of additional cycle pathways and a change to more efficient street and traffic light solutions. These municipal funds however will not make the City of Copenhagen carbon neutral, and therefore Jørgen Abildgaard emphasises that most of the transition is actually funded indirectly through investments that take place in Copenhagen independent of the climate plan e.g. infrastructure projects. He remarks: "a big part of our job is to influence those investments and ensure that they also support the vision". This requires great collaboration with multiple stakeholders in Copenhagen. In terms of the municipal funding, Jørgen Abildgaard finds that the overall funds have been quite alright, however it has been difficult to get resources for some of the underlying processes that are needed to activate the implementation plan e.g. research and citizen involvement projects. He contends:

> *Politicians will rather open a new school than prioritise funds for an 'invisible' process. That's the game, and I understand it, but you have to very aware of the fact that this has a consequence since those invisible processes are also necessary.*

In defining carbon neutrality, the CPH 2025 Climate Plan relies on the so-called CO_2-calculator, a tool that has been developed by the Organisation of Danish Municipalities and the Ministry of Environment and Food. The tool calculates emission within the geographical boundary of the municipality, and neutrality is achieved when "the production of renewable energy power equals the quantity used by the city. In the event of renewable energy production exceeding the demands of Copenhagen, the amount will displace coal-based power production elsewhere" (City of Copenhagen 2012:11). As in Sonderborg emissions from products that are imported and exported are not added or subtracted, however, when HOFOR Wind, puts up wind turbines in other municipalities the electricity produced by these count towards Copenhagen's carbon calculations. In 2012, the first of three implementation plans was published. This plan includes goals and initiatives that are to be achieved between 2012 and 2016. The implementation is divided into four main themes: energy consumption, energy supply, city administration and mobility. The analysis of this case is focused on goals set out in the energy supply theme[4].

[4] Four initiatives under the theme of energy supply concern treatment and sorting of household waste. To retain the narrow scope of analysis these are not included. This is justified on the basis that they are more concerned with user recycling practices rather than strictly related to energy supply.

6.1 Geographical Context: Cementing Copenhagen's Green Image

In line with the theoretical understanding that geography matters, this section sets out to introduce the city of Copenhagen in more detail to explore the context within which the capital's carbon vision is situated. It is suggested that the CPH 2025 Climate Plan should be seen in the light of Copenhagen's long-standing efforts to brand the city and Denmark as green frontrunners.

Figure 4: Map of the City of Copenhagen

The City of Copenhagen is part of the larger Copenhagen conurbation. As displayed in figure 3, the municipality covers large parts of the city centre and stretches east to the water front. The urban context that characterises Copenhagen is in multiple instances different to that in Sonderborg. The city is characterised by a compact, build up urban area and the latest census states that the municipal population amounted to 591,481 people. Unlike Sonderborg, where the population is decreasing, Copenhagen is experiencing population increase. Since 2010, the population in the City of Copenhagen grew with 12% (Danmarks Statistik 2016[5]). In terms of the area's economic landscape, the capital is a lot more diverse than Sonderborg. It "hosts headquarters for many of

[5] The population change is calculated on the basis of statistics from the first quarter in 2010 and the first quarter in 2016.

Denmark's large companies and branches of global corporations, but it is also home to thousands of small and medium-sized enterprises" (LSE Cities 2014:56). The city is also characterised by a diverse labour market and one of the highest levels of tertiary education in Europe. In terms of green goods and services Copenhagen hosts a large cleantech cluster (LSE Cities 2014).

Copenhagen is internationally recognised as a green frontrunner and was in 2014 awarded the title European Green Capital for its climate mitigation and adaptation initiatives (European Commission 2014). Copenhagen is arguably a "trendsetter for climate change branding" (Busch and Anderberg 2015:2), whereby environment and sustainability related actions are used to create a positive place image (Anderberg and Clark 2013). The CPH 2025 Climate Plan and its focus on combining green growth and ensuring a high quality of life amongst local residents suit this green narrative very well. According to Jørgen Abildgaard, the carbon vision is a continuation of a much longer tradition:

> *The focus on the environment is not something that we have made up the last couple of years. Rather the green profile is in our DNA. That is also why it is very natural that Copenhagen has taken on this role.*

Following national strategy to secure energy supplies, the City of Copenhagen has worked to improve resource and energy efficiency for more than thirty years. The city's district heating system illustrates this well. Massive developments to the infrastructure took place in the 1980s following the oil shocks in the 1970s, and today 98% of the city's heat demand is met by district heating (Københavns Energi 2005). Today, this efficient heat infrastructure is an important foundation on which the city's green image has been built. Jørgen Abildgaard remarks:

> *We still have to make many changes, but our infrastructural starting point was very different from most places in the world […] our carbon transition is taking place as a continuation of developments that happened long before we defined this vision.*

Copenhagen's promotion as a green frontrunner is believed to benefit Denmark as a whole. Frank Jensen, pinpoints this well:

> *I see the vision as an important cornerstone in Copenhagen's role as an engine of growth for Denmark. With the Climate Plan we are investing in an area, which is highly specialised and with a great potential for exports.*

Frank Jensen's emphasis on Copenhagen as an 'engine of growth for Denmark' reflects larger developments in Danish planning, in which the role of Copenhagen has changed quite significantly over recent decades (Carter *et al*. 2015). Since the late 1980s, narratives of competition and growth have impacted the trajectory of Danish planning and Copenhagen has changed from being spatially envisioned as "one town among many Danish towns" to increasingly being imagined as "'the growth locomotive' of all Denmark" (Lund Hansen *et al*. 2001). The carbon vision can be understood to further emphasise the role of Copenhagen in the Danish context.

The carbon vision's growth agenda is moreover in line with the plan's ambition to showcase green solutions to the world: "a carbon neutral Copenhagen will provide Danish business with a common platform and a showcase for demonstrating green Danish technology (City of Copenhagen 2012:11). In this sense the cases in Copenhagen and Sonderborg are very similar but due to Copenhagen's national importance the imagined scale of impact is greater. Jørgen Abildgaard insists that the role of demonstrator is a key dimension of CPH 2025 Climate Plan. He argues that the transition to carbon neutrality will not make a big difference in terms of international carbon levels "but through demonstrating that a small global city can make the transition we help create knowledge that can be used in other places around the world". These broader advantages, creating possibilities for showcase and green growth, are arguably key reasons why the vision has enjoyed such widespread political support.

6.2 Energy Supply in Copenhagen

In a similar manner to ProjectZero, the CPH 2025 Climate Plan intends to achieve an intelligent energy infrastructure based on renewable sources. Changing the system of energy supply is a crucial means to realise this goal. As mentioned Copenhagen is characterised by an extensive collective heating infrastructure that supplies 98% of heating demand in the city. In 2010, before the publication of the first implementation plan, district heating was based on the following fuels: natural gas (32%), biomass (22%), coal (20%), waste (17%) and fuel oil (9%). During that same year, electricity demand in the municipality was met by the following sources: coal (42%), wind, hydro and solar power (22%), natural gas and oil (21%), waste, biomass and biogas (13%) and nuclear (2%) (LSE Cities 2014:69-70).

By 2025, the CPH 2025 Climate Plan sets out to attain a multi-sourced, flexible and carbon neutral energy supply. Since the distributional infrastructures are in place in Copenhagen the carbon vision is focused on changing the production of energy. Two overall strategic goals are to make this happen. First, the production of district heating should be changed to carbon neutral sources; in the short term biomass and waste incineration, while heat pumps and geothermal production should be included in the long term. Second, the production of electricity should be based on wind and biomass. In terms of wind power the municipality aims to build turbines with a combined capacity of 360MW (City of Copenhagen 2012). The production of electricity should exceed the city's consumption so that export of 'green' electricity can make up for transport emissions that are not expected to be carbon neutral by 2025. These overarching goals are broken down in three implementation phases. The specific goals that relate to energy supply in the first phase, which lasts from 2012 to 2016, are outlined in table 3 below. The table also includes a short description of the current status for each goal. The remaining part of this section departs from table 3 to further explore the extent to which these goals have been met and uncover reasons why some of them have not been met.

Wind Power

A majority of the goals in table 3 are concerned with wind power. HOFOR, the city's utility company, is in charge of executing the wind ambition, which includes projects both onshore and offshore. HOFOR is working to establish a number of onshore turbines within the boarder of the municipality, but mostly in other municipalities to overcome space constraints in the city.

In line with the implementation plan, four sites within the city were identified as potentially suitable for putting up turbines: Prøvestenene, Nordhavn, Kalvebodkysten and Lynetten. In 2013, three turbines were put up at Prøvestenene; however, the aim of concluding the planning process for seven turbines has not been achieved, mainly because plans at two of the selected sites were suspended. Jørgen Abildgaard explains that in 2011, after extensive pressure from the municipality of Gentofte, national government changed the planning law in Nordhavn so that four planned turbines could not be put up at the site. Later, the plan to build four turbines at Kalvebodkysten was terminated in 2015 after the Environmental Board of Appeal decided in favour of the municipality of Hvidovre, the Danish Ornithological Society, the Danish Society of Nature Conservation and the Homeowners Association Strandvang, who complained that the plan had been given an inappropriate exemption from the coastal protection law. According to project developer at HOFOR Wind, Christina Rolandsen, Lynetten is still a potential site for wind turbines, however the area is located near Refshaleøen where the municipality is potentially looking to build housing – "there are certainly pieces that must fall into place so that the two don't exclude each other, but the potential is there". In terms of onshore wind turbines in other municipalities, Jørgen Abildgaard remarks that the process is "on track" as HOFOR expects to have put up turbines with a power capacity of 60MW by the end of 2016. Christina Rolandsen largely concurs, but extends her assessment of the progress by explaining that since the start of the implementation plan, the process of establishing new onshore wind parks outside Copenhagen is faced with new challenges. Local resistance to onshore wind parks is growing across the country, and municipal politicians have started to implement local legislation that in some cases make it harder for plans to be approved.

Table 3: Energy supply aims in the first phase of CPH 2025 Climate Plan (adapted from the City of Copenhagen 2012)

Stated goals	**Current status**	**Source**
Onshore wind: identify four sites in Copenhagen with room for 14 turbines.	**Partly completed:** Four sites were identified: Nordhavn, Kalvebodkysten, Prøvestenene and Lynetten. Two of the sites, Nordhavn and Kalvebodkysten, have subsequently been rejected.	Københavns Kommune (2013)
Onshore wind: conclude planning process for seven turbines within the municipal boarder (expected to be done in 2013).	**Partly completed:** In 2013, three turbines were set up at Prøvestenene.	HOFOR (2014)
Onshore wind: establish wind turbines in other municipalities. Negotiate with landowners about potential sites.	**Completed:** this is a continuous goal, but so far 6.9 MW have been established in Billund, a total of 44.9 MW have been put up across three locations on Lolland and 6 MW are being put up in Lemvig by the end of 2016.	Christina L. Rolandsen (Interview)
Offshore wind: encourage the government to lay down favourable framework conditions.	**Unknown:** Favourable framework conditions were ensured in the 2012 Energy Agreement, but the Danish government has recently proposed that the near shore wind tender, which was set out in the 2012 Energy Agreement, should be cancelled.	Jørgen Abildgaard (Interview) Maach (2016)
Offshore wind: examine possibilities of establishing partnerships to bid on state-owned offshore wind projects.	**Completed:** HOFOR has established a partnership with the German company wdp. They are bidding for the large-scale offshore wind tenders.	HOFOR (2015)
Offshore wind: install offshore wind turbines on two predetermined sites.	**Not completed:** HOFOR has bid for the project at Kriegers Falk, while the near shore projects are delayed and politically discussed.	Danish Energy Agency (2016ab) Maach (2016)

Table 3: continued

Stated goals	**Current status**	**Source**
Draft decision-making basis regarding the establishment of a new waste incineration plant.	**Completed:** In 2012, a decision was made to build Amager Hill.	Amager Resource Center (N/A)
Analyse possibilities for transforming peak load productions to CO_2 neutral fuels.	**Completed:** the issue is still on the agenda and being analysed, priority however is given to a transition of base load production.	Nina Holmboe (Interview)
Negotiate transition to biomass at CHP plants at Amager and Avedøre.	**Completed:** Amager power station has two production blocks. One is based on biomass production the other on coal. A decision has been made to covert the coal-based block to biomass. The conversion is expected to commence within the coming years. Avedøre power station also has two production blocks. One is based on biomass production the other on coal. The coal block is currently being converted to a biomass block. The conversion is expected to be done by the end of 2016.	DONG Energy (2015) HOFOR (N/A)

As outlined in section 4, current political discussions in Denmark are very directly related to offshore wind power. These developments however had not taken place when I carried out the interviews for the thesis. Therefore, when discussing the offshore goals in Copenhagen's plan, I will first consider the insights developed from the interviews and then subsequently reflect on the recent political developments.

The aim of installing offshore wind turbines on two predetermined sites has not been achieved during the first implementation phase, but the prerequisite goals leading up to an eventual installation have largely been attained. The aim of encouraging favourable framework conditions was achieved through the 2012 Energy Agreement, which committed to ensuring a substantial development of additional wind power in Denmark. HOFOR's offshore strategy has particularly been aimed at two of the large-scale state tenders that were secured in the agreement, these include the offshore tender at Kiegers Falk in the Baltic Sea as well as the near shore tender for six wind farms located along the Danish coast. Following the implementation plan HOFOR established a wind consortium in order to bid for the state tenders. In 2015, a partnership with the German wind operator and developer, wpd, was announced (HOFOR 2015). During April 2016, HOFOR and wpd placed bids for the tender at Kiegers Flak. It is too early to say whether the bid was successful, but as Jørgen Abildgaard remarks: "HOFOR has to actually win some of the bids for it to matter in terms of our vision".

The situation with the near shore tender is slightly more complicated. The deadline for final tender has been postponed from 1st April 2016 to 1st September 2016 (Danish Energy Agency 2016b). Christina Rolandsen explains that this is partly due to the current political discussions about the PSO tariff, but also due to complications with the environmental assessments, which has resulted in one of the six sites being cancelled. Since the interview with Christina Rolandsen, the situation has developed somewhat. On Friday 13th May 2016 the Danish Government announced that they propose to cancel the near shore wind tenders, in order to mitigate the costs that will arise from abolishing the PSO tariff (Nielsen 2016). Although a final decision has not yet been made, head of HOFOR wind Jesper Pedersen has stated that this proposal can ruin the municipality's chance of reaching its goal of carbon neutrality. He remarks:

> *It is surprising and very unfortunate that we have a minister who cannot secure the long term planning and stability needed for a green transition [...] It is a big step away from the proud tradition we have in Denmark where energy transitions are supported by big investments, long-term perspectives and stability. International investors are not going to invest unless conditions are stable* (Badstue Pedersen 2016:online).

It will be very interesting to follow this issue when the government continues negotiations after the summer break. As of now one can argue that the situation illustrates how long-term investments in the energy infrastructure depends on consistent national legislation and political stability.

Production of Heat

Moving on from wind power, the implementation plan states that a decision regarding a new waste incineration plant should be drafted. The goal was achieved in 2012, when a decision was made to build the incineration plant, Amager Hill. Although Amager Hill seems to meet the implementation goal, it is clear from the interviews and media coverage that the current solution is highly disputed.

The plant is part of the waste management company, Amagerforbrændingen, which is owned by five municipalities, Copenhagen, Frederiksberg, Hvidovre, Tårnby and Dragør. Since its initial planning, Amager Hill has been a topic of intense political debate. Discussions have particularly regarded the size of the plant. In an attempt to encourage recycling, the municipality of Copenhagen initially blocked the planned construction of a plant with a capacity of 70 tons per hour. However, six months later the municipality entered into an agreement to build a plant with a capacity of 60 tons per hour. Although smaller than the first proposal, critics argue that the capacity of the new plant is still too big to provide a proper incentive for developing new recycling technologies and practices (Dandanell 2012).

Bo Asmus Kjeldgaard was able to provide insight into the political negotiations. He suggests that the disagreement over size was bound up in a larger discussion about merging Amagerforbrænding with the waste management company Vestforbrænding, which is owned by 19 municipalities in the larger Copenhagen area. He argues that the plan to construct the large plant relied on the assumption that both waste management companies, and a total of 26 municipalities would use it. However, the merger fell through because smaller municipalities vetoed the merger in fear that they would lose power in a larger company constellation. Due to multiple circumstances it was not possible to draft a new proposal. Bo Asmus Kjeldgaard explains:

> *The entire process got very muddled up and we were so far in the tender process that it was difficult to start over again [...] Moreover, we needed a solution quite quickly because we were spending so much money on repairing the old oven. The whole thing ended in a stupid situation where even though you only wanted a small oven you had to vote for a big one.*

The size of the plant continues to be a topic of discussion. The latest calculations predict a large economic deficit because there is not enough waste in Copenhagen to supply the plant (Andersen 2016). Allowing import of waste is discussed as a potential solution to the economic problems. However, this could jeopardise Copenhagen's carbon vision as imported waste has lower standards regarding plastic sorting and the incineration might therefore produce a higher level of greenhouse gas emission (Bredsdorff and Wittrup 2015). From talking to Jørgen Abildgaard it was clear that the decision to build the larger plant is not only an obstacle in terms of recycling ambitions and the potential impacts from imported waste, but also in terms of developing a flexible system of energy production. He argues:

> *It's way too big! […] The plant produces such a large base load that some of the other initiatives that we wanted to do with heat pumps and geothermal power are less interesting because they can't compete economically. As such we are loosing the flexibility that we wanted the system to have.*

Nina Holmboe from HOFOR District Heating describes this economic aspect further. She explains that producing heat with waste incineration is prioritised in Copenhagen, as in the rest of Denmark. Heat from waste incineration is cheap and consequently meets a basic premise in national heat legislation; that prices should be kept low. Building a big incineration plant thus predetermines a large amount of the heat production, which makes it difficult for other sources to compete. It is consequently less profitable to install renewable technologies, and Jørgen Abildgaard argues that this is one of the reasons why the goal of establishing renewable heating solutions has not been fully met.

The final goals in the implementation plan are related to the introduction of new renewable sources in heat production. Before exploring these specific aims it is worth noticing that Copenhagen's district heating infrastructure is part of a larger metropolitan district heating system that "connects four CHP plants, three waste incinerators and more than 50 peak load boiler plants with more than 20 distribution companies in one large pool operated system" (Københavns Energi 2005:5). HOFOR supplies Copenhagen with district heating and they own production plants, but they also buy heat from multiple production sites both within and outside the municipality. This is important to keep in mind because the carbon vision set out in the CPH 2025 Climate Plan is municipal, but the infrastructure actually works across multiple municipalities and involves many different actors and stakeholders.

In collaboration with the major heating companies in Copenhagen, CTR (Central Kommunernes Transmissionsselskab) and VEKS (Vestegnens Kraftvarmeselskab), HOFOR has carried out Heat Plan Greater Copenhagen, which aims to achieve a carbon neutral energy supply in the entire metropolitan area by 2025 (CTR *et al*. 2014). Nina Holmboe explains that the major heating companies in Greater Copenhagen - CTR, HOFOR and VEKS - as well as the 17 municipalities behind CTR, HOFOR and VEKS all agree on carbon neutral district heating by 2025. As the grids of the three companies are interconnected, CTR, HOFOR and VEKS are co-dependent in achieving the collective goal. Heat Plan Greater Copenhagen sets the collective framework for CTR, HOFOR and VEKS - towards achieving the goals for the collective system, but Nina Holmboe emphasises that: “although we see Heat Plan Greater Copenhagen as one collective goal and system, it is still made up of three different companies with three different organisations. This sometimes challenges the collaboration and makes the task more complex”. As an example HOFOR owns only a small minority of the peak load plants in the district heating system in Greater Copenhagen and is therefore dependent on CTR and VEKS when trying to transform the peak load production to carbon neutral fuels. In line with the implementation plan, the three companies are currently analysing the possibilities of transforming peak load productions. However, this is a particularly expensive transition compared to base load plants because peak load productions are used much less. According to Nina Holmboe, the companies are only currently trying to agree whether the transition is worthwhile for all partners.

In terms of base load production, a key aim in the implementation plan is transitioning from fossil fuels to biomass at the two large CHP plants (Amagerværket and Avedøreværket). Agreements have been made and the transition is underway. HOFOR acquired the plant at Amager in 2014, which according to Bo Asmus Kjeldgaard made the process easier. The plant at Avedøre is owned by DONG Energy and negotiating a transition there was harder. At the time Bo Asmus Kjeldgaard was mayor of the Technical and Environmental Administration. He negotiated the transition with DONG Energy and found that Copenhagen in this instance benefitted from being part of a larger district heating network, where multiple municipalities together had a greater bargaining power:

> *I had a long conflict with Anders Eldrup [then CEO in DONG] because he wouldn't get rid of coal at Avedøre [...] But at the time I was chairman at CTR and I got all five municipalities to agree that we would only buy carbon neutral heat from Avedøre [...] in the end he actually gave in and now biomass is on its way.*

To briefly sum up the case of CPH 2025 Climate Plan it is clear that the urban sustainability experiment is benefitting from Copenhagen's pre-existing green image and previous investments such as those made in the collective heating infrastructure. The experiment is also benefitting from political agreements on the national scale, such as the 2012 Energy Agreement, which created favourable framework conditions for long-term investment. It is not possible at this point to say whether the Danish government's recent proposal to cancel the near-shore wind tender will influence the CPH 2025 Climate Plan, but the concerns that have been raised following this proposal stress the challenges that can arise in the face of inconsistent national legislation. On the scale of local authority, political inconsistencies can likewise hamper the experiment, as is the case when politicians neglect investments in the more invisible processes that support the vision. The CPH 2025 Climate Plan is also clearly hindered by the growing opposition to onshore wind power, which has impeded onshore projects inside the City of Copenhagen, and which increasingly challenges projects in other municipalities. Finally, the fact that the infrastructural networks are not confined to the geographical space of Copenhagen’s vision can in some instances be an advantage and other instances a disadvantage for the urban climate change experiment.

CHAPTER 7

COMPARATIVE ANALYSIS

The thesis sets out to answer two research questions. First, with reference to energy supply it tries to uncover mechanisms that aid and hinder two Danish experiments' attempted transition to carbon neutrality. Second, the thesis attempts to build an understanding of the extent to which the two experiments' different geographical contexts influence these mechanisms. First, this comparative analysis considers mechanisms that are common across both cases. Second, the analysis discusses mechanisms that arguably are linked more to the experiments' geographical characteristics and which differentiate the experiments from each other. The analysis challenges some of the theoretical assumptions relating to the effectiveness of climate governance at the scale of experiments, and instead suggests that our understanding of the influence should be nuanced.

7.1 Common Mechanisms

A key mechanism that appears to act as an aid in both cases is that the experiment visions very clearly depart from an understanding that climate mitigation not only imposes costs, but also has the potential to bring benefits. Both experiments set out to demonstrate that a transition to carbon neutrality can be accompanied by growth. At ProjectZero, the aim of contributing to the global problem of climate change is intimately linked to also solving local challenges that arise from an aging population and struggles to attract qualified labour. The area wants to capitalise on the green agenda to support the local knowledge base and industrial make-up. Sonderborg's mayor clearly states, "ProjectZero is not philanthropy", which underlines the expectations of achieving benefits. Similarly, Copenhagen's Lord Mayor underlines the economic opportunities that follow from setting an ambitious climate agenda: "I see the vision as an important cornerstone in Copenhagen's role as an engine of growth for Denmark". CPH 2025 Climate Plan aims to demonstrate how a small global city can transition to carbon neutrality, but simultaneously this demonstration builds a positive place image by branding Denmark and the City of Copenhagen as green frontrunners. This multi-dimensional aim helps legitimatise the experiments and the investments that follow. In both experiments the systems of energy supply exemplify this well. Realising initiatives towards a carbon neutral system of energy supply has environmental benefits, but it also provides an important showcase. The energy infrastructure in Sonderborg showcases local producers, while the infrastructure in Copenhagen showcases Danish solutions more broadly.

Economic opportunity is also an important aiding mechanism in many of the successful goals in both experiments. In terms of heating, this relates back to the cornerstones of Danish national heat legislation: the non-profit principle, coast based pricing, and the intent to keep heat supply at price as low as possible for the consumer. These fundamental principles mean that only projects, which are believed to be economically viable, are approved by municipalities and carried out. Copenhagen's successful move towards biomass at the CHP plant in Amager as well as the decision in Sonderborg to expand district heating and put up solar panels and a geothermal plant rely on internal business cases that are economically well-grounded. However, the mechanism of economic viability and opportunity are factors that the urban climate change experiments have very little influence on.

Although Danish municipalities approve and reject proposals related to heating, the economic viability of projects is determined by multiple external circumstances. For instance, in the ProjectZero case, the price of natural gas is mentioned as a determining circumstance that currently inhibits the economic viability of projects set out to expand district heating networks. In both cases, national taxes and tariffs on fuels also impact the viability of projects. Biomass projects are currently supported by tax exemptions, while heat pumps in district heating systems are penalised by for instance the PSO tariff. Through taxes and tariffs the Danish state is regulating the energy market, which in turn impacts the local infrastructural changes.

This is a really interesting finding in terms of the literature on urban climate change experiments and the arguments that are put forwards about the impacts of governance at the scale of the city. In theory, climate governance at the scale of the city is believed to offer more effective policies, and one of the main reasons for this is that local authority is generally understood to be in charge of the city's public service and systems of infrastructure (Bulkeley *et al.* 2015; Coutard and Rutherford 2010). But perhaps this understanding needs to be nuanced. Both cases suggest that in the Danish context urban authorities' agency over the system of energy supply infrastructure is, to a great degree, influenced by for instance national legislation as illustrated above. In a similar vein, the Danish government's recent proposal to cancel the planned near shore wind tender potentially jeopardises the wind ambition in the CPH 2025 Climate Plan, a key component in the experiment's energy supply transition. This also illustrates the dependency between local infrastructure visions and stable national policy. Both examples show a politically embedded nature of urban climate change experiments and a dependency on other policy scales.

The experiments are not only politically embedded but also technologically embedded since infrastructures are not confined to the scale of the experiments. This particularly comes across with regards to Copenhagen's collective heating infrastructure, which extends beyond the City of Copenhagen. Again this embedded-ness creates a dependency on actors outside of the experiment, which for instance shows in terms of the transition of peak load production where HOFOR rely on the willingness of VEKS and CTR to invest and change. The case of CPH 2025 Climate Change also shows that the experiment's embedded nature can be an advantage, as it was when the municipality of Copenhagen convinced DONG Energy to transition to biomass at Avedøre CHP plant. Here, the collaboration with co-dependent actors created a greater bargaining power.

Furthermore, technological embedded-ness can be thought of in relation to both experiments' electricity goals. The experiment goals focus on changing sources of production, particularly through the introduction of increased wind power. However, in both experiments none of the goals are concerned with developments of the transmission or distribution networks, which, as illustrated in chapter four, is necessary to ensure continued economic profitability and efficiency with the increased wind power. The omission of goals relating to transmission and distribution networks highlights an area of energy infrastructure where the urban climate change experiments currently do not manage to effectively govern or take responsibility. This further emphasises the argument that we should nuance our understanding of how influential urban governance is when it comes to infrastructural transitions.

In the literature, urban climate change experiments are also described as prone to contestation, conflict and diverging priorities. These are indeed characteristics that are also reflected in our two cases, where conflicts hinder goals from being achieved. The resistance to, and conflict over onshore wind power illustrates this well. In both experiments, aims relating to onshore wind power within the municipality borders have not been achieved because of resistance to turbines. In Sonderborg, the resistance has been coming from local residents within the municipality, where as in Copenhagen, resistance has particularly been coming from neighbouring municipalities. In both cases, this illustrates a difficulty of mobilising and involving stakeholders, be that either local citizens or neighbouring communities. Again this finding nuances the theoretical understanding that local initiatives are able to make issues more relevant to concerned stakeholders. This is not to say that local initiatives do not manage to do that at all, but the cases show that the difficulties of involving stakeholders still exist at the scale of urban climate change experiments.

The construction of the larger Amager Hill and the lawsuit between the municipality of Sondeborg and the local utility companies are also examples that illustrate how diverging priorities create challenges for the experiments. In Copenhagen, conflict and diverging priorities are arguably underpinning reasons why Amager Hill was constructed at size that decreases the flexibility of the city's energy system, and actually makes it more economically difficult to introduce other renewable sources of energy. The decision in Sonderborg, to retrospectively charge a commission on loan securities represents a political priority that economically penalises the local utility cooperative's active contribution to the area's energy supply goals.

7.3 Geographical Mechanisms

Urban form stands out as a particularly influential spatial characteristic since it fundamentally impacts the systems of heat supply in both experiments. The compact urban form in Copenhagen makes it possible to provide heat through one collective infrastructure, while areas with low population densities in the municipality of Sonderborg rely on individual heating solutions. One urban form is not necessarily better than the other, but the different outsets result in quite distinct mechanisms that act both as aids and hinders. In Copenhagen, the city's extensive heating infrastructure means that a transition towards carbon neutral heating 'only' requires a change of source in the large production sites. Although Sonderborg is working towards a more expansive collective infrastructure, parts of the municipality will continue to rely on individual heating sources because the collective infrastructure cannot be established in some of the municipality's sparsely populated and more remote areas. Individual heating sources place a very different responsibility on homeowners or landlords, since the experiment visions need not only convince stakeholders at large sites of production to change the source, but must convince individuals to change their household heating source. This requires a different level of citizen involvement and often an economic commitment because changing from, for instance, an oil furnace to heat pumps and solar panels requires an upfront investment. Municipalities can encourage households to change and support the transition through information events and campaigns; however, they rely on the state to make legislative changes as was done in the 2012 Energy Agreement.

The ProjectZero case moreover suggests that an area's demography plays a particular role when it comes to changing individual heating sources. It is suggested that Sondeborg's aging demographic, which is particularly pronounced amongst individually heated households, makes the transition more difficult because the elder generation is more reluctant to invest. The impact of demography is only tentatively suggested here, but the proposition reflects findings from larger-scale quantitative studies that have been carried out in Denmark. For instance, Mortensen *et al.* (2014) survey Danish single-family house owners' need and willingness to carry out energy retrofitting. They find that respondents above the age of 60 are less interested in energy retrofitting compared to younger generations, and that it is difficult to motivate the older generations to invest a larger sum of money. The elder generation is arguably "more satisfied with the current state of their house and do not see the same need for retrofits as the younger generation" (Mortensen *et al.* 2014:473). These findings match suggestions that are made in the ProjectZero case very well.

CHAPTER 8

CONCLUSION

Effectively steering societies towards preventing, adapting and mitigating the risks of climate change has been an issue of contestation and concern for more than three decades. For many years climate governance has mainly been concerned with the multilateral approach, which relies on nation states committing to international agreements and reduction targets. However, as an approach to climate change the multilateral approach has been largely ineffective, and bottom up approaches have more recently proliferated around the world. This has led scholars to suggest that a new experimental governance approach to climate change is emerging. Cities are understood to be particular important spaces for this development as they provide a protected environment, which helps facilitate the growth of experimental governance approaches. As cities and urban climate change experiments are heralded as key sites for sustainable innovation and climate governance, it is increasingly important to assess whether climate change experiments in urban areas bring about fundamental changes to climate change mitigation and adaptation – are they an effective and successful response?

In trying to address this issue, the thesis has examined two Danish experiments in two different urban contexts that both aim to achieve a transition to carbon neutrality. Following Hodson and Marvin's (2011) analytical framework for assessing effect, the thesis has considered concrete aims and objectives in both experiments. It has looked at the extent to which these aims and objectives have been met and has tried to uncover what mechanisms hinder and aid the experiments. To narrow the scope of analysis, the thesis has specifically focused on goals related to energy supply. Through the comparative design, the thesis also attempts to instil a more spatially informed analysis that attempts to build an understanding of the extent to which the two experiments' different geographical contexts influence these mechanisms. Knowledge of the cases was gained through semi-structured stakeholder interviews and desktop research. Each case was first presented individually and subsequently compared.

Across the case analyses, common mechanisms, which influence the ability to achieve experiment goals in both experiments, are identified. First, economic opportunity is believed to help legitimise spending and investments in both experiments. Economic viability is moreover identified as an important aiding mechanism in many of the successful goals since an economically well-grounded business case is a condition for achieving approval for infrastructural projects at the municipal scale. Second, the embedded nature of both experiments impacts their ability to achieve experiment objectives. In these cases, the embedded-ness and dependency mostly challenges the experiments, for instance when national legislation does not match or support the experiments' frontrunner visions. Finally, conflict, particularly local resistance to onshore wind, and diverging political priorities challenge both experiments. It highlights the difficulties of engaging local stakeholders and emphasises the struggle that exist to keep the climate agenda a top priority. These mechanisms come across as largely unrelated to the experiments' local context, but can perhaps better be understood with regards to their common situation in the Danish context. Wanting to make an infrastructural transition twenty years before the rest of the country creates legislative barriers, and poses problems of collaboration when actors that the experiments rely on do not share the same ambition. In terms of the literature on urban climate change experiments, these findings challenge the theoretical assumptions that climate governance at the scale of the city is effective because local authority is better equipped to engage local stakeholders and have a high level of influence over the city's infrastructure. The thesis does not claim that urban climate governance through experimentation is less or more effective than for instance national climate governance, but the case analyses demonstrate that the local experiments struggle with mechanisms that in theory are considered their main advantage. This suggests that the theoretical understanding should be nuanced.

Although the local context does not come across as a main influencer in all mechanisms, local geography still matters as is illustrated in terms of the impact of urban form. The urban forms of both experiments create a very fundamental outset from which the experiments' heating infrastructure is based. The resulting infrastructure, the collective system in Copenhagen and the combined collective and individual system in Sonderborg, creates different barriers and opportunities that certainly differentiate the experiments from each other. It is suggested that Sonderborg's local demography for instance challenges the transition of individually heated households.

On a final note, it makes sense to take a step back and reflect on the concept of urban climate change experiments from a more general perspective. The entire thesis is built around the assumption that achieving the experiment goals will lead to greater sustainability, but it is worth challenging this assumption especially in terms of how the experiments define carbon neutrality. As mentioned in the case analyses, both experiments exclude imports and exports in their carbon calculations, and ProjectZero moreover excludes air and sea transports. These selective parameters arguably mean that we risk getting a very skewed impression of the actual impact of the experiments, since the climate continues to suffer from the production and transportation that is not accounted for, but which goes towards sustaining the two areas. Elements of the CPH 2025 Climate Plan are also very short sighted. For instance, a key goal of the CPH 2025 Climate Plan is that power production should exceed the city's consumption so that export of 'green' power can make up for the city's transport emissions, which are not expected to be carbon neutral by 2025. This means that Copenhagen's carbon neutral vision relies on the assumption that Copenhagen can continue to export green energy to other places that rely on energy produced by fossil fuels. This logic makes sense in terms of the city's calculations, but it clashes with the global character of climate change. If we focus too much on climate governance at the scale of experiments, and largely neglect the larger perspective then there might be a risk of creating islands of theoretical carbon neutrality in a sea of continued unsustainability. Achieving the objectives should not be considered the main goal, but instead the ambitious urban climate change experiments should be valued for their ability to create national momentum and put pressure on other political scales to enable transition.

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APPENDIX I

INTERVIEW GUIDE EXAMPLE

Translated guide used for the interview with Jørgen Abildgaard

1. **Recording and anonymity**

- Can I record the interview?
- Can I use your name in the thesis?

2. **Organisational set-up**

- Tell me more about the climate secretariat.
    - How many are employed, what is the role of the secretariat?
- Tell me more about your role.
    - Was it 'created' when the vision was formulated in 2009?
    - Is anything different or possible with this role, that was not possible before?

3. **The vision**

- How and when did the vision of a carbon neutral Copenhagen come about?
- What does the vision mean for Copenhagen, why?
- Is it solely a political vision, why/why not?
    - Does this aid or hinder the vision, how and why?
- How is the vision financed?
    - Are there particular opportunities or challenges because of this?
- Since you took on this role in 2010, what are in your opinion the greatest achievements that have been made towards realising the vision, why?
- What have been some of the greatest challenges, why?
    - How have you dealt with these challenges?
- What are currently some of the greatest challenges in realising the vision?
- How confident are you that you will achieve the vision?
- Is the vision sustainable?

4. **Energy supply**

- Use the table with listed goals relating to energy supply as a tool for conversation. Go through the individual goals and discuss:
    - What is the current status of the goal?
    - Why has the goal been achieved or not achieved?
    - What role has the secretariat played in achieving the goal?