Electrification of Construction: Investigating Actor Roles and Interactions in Cross-Sector Sustainability Experiments

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Abstract

This thesis investigates actor roles and interactions in cross-sectoral sustainability experiments, through conducting a single-case study on the case of electrification of construction sites in Norway. The thesis belongs to the field of sustainability transitions, which has gained criticism for paying too little attention to the actor perspective in transitions. Further, an emerging view of transitions is how they increasingly involve multiple sectors, which entails interactions across actors from multiple systems. Thus, this thesis attempts to expand on existing research, through investigating the role of actors as they interact with others across sectors in experiments for sustainability.

To contribute with insight to this research, a case study was conducted on the case of electrification of construction sites in Norway. The use of electrical machinery at construction sites are a relatively new phenomena in an early stage of transition, as it is dominated by pilot projects, and subsidy programs aimed at creating knowledge and developing solutions. In this research project, the aim was gaining insight on actor level dynamics of cross-sector sustainability experiments. Thus, the focus of the research design was gaining insight from actors participating in pilots or other types of experiments aimed at testing the use of electrical machinery at construction sites.

Among the findings was how experimental projects constitutes *sites of interaction* between actors from different sectors, where new and strengthened linkages between actors are made. Further, due to the problem-solving approach and new tasks that emerge through the sustainability experiments, actors take upon new and untraditional roles to secure successful experimentation. However, as transitions are in an early phase, these roles are likely to change as the transition unfolds. Accordingly, the allocation of roles in transitions involving multiple sectors may evolve over time. Lastly, the thesis concludes with suggestions for further research on actors in early stages of transitions involving actors from multiple sectors.

Acknowledgements

With this master thesis, I conclude my education at the University of Oslo. The past year as a master student at the Centre for Technology, Innovation and Culture have been challenging, but also given me much insight on interesting topics, and new ways of thinking I will take with me on future endeavors.

I wish to express my sincerest gratitude to my thesis supervisor Jakoba Sraml Gonzales for being supportive every step of the way of writing this thesis, and for all the valuable feedback.

This thesis partly came to being through my participation in the UiO: Energy summer program from which I did data collection on the project *Pathways* at the Centre for Technology, Innovation and Culture over the summer and autumn of 2021. The data collection process of this thesis highly overlaps with the material for this project. Any conclusion and analysis of this thesis, however, are my own and not tied to the project. This project, however, would not have been the same without guidance and support from Hilde Nykamp, as my project supervisor from the UiO: Energy summer project.

Thank you, to all the informants that have been positive about discussing their work with me, and thus contributing to this research project. This thesis would not have existed without your help.

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1. INTRODUCTION

1.1. Research Area and Question

As the climate changes have become more pressing, substantiated by the IPCC report of 2021, state leaders look for ways to reduce national carbon emissions to reduce the damage of climate change (IPCC, 2021). After the Paris Agreement was established in 2015, specific targets for decarbonization were set, and Norway committed to reduce up to 55% percent within 2030. Executive Secretary of UNFCCC states that a transition towards renewable energy is crucial for reaching set targets, as two thirds of global greenhouse gas emissions can be traced back to industry processes and use of fossil fuels (UN Climate Change 2021). However, a transition in the energy system will require massive shifts in technology and infrastructure and is not a task for one single actor to solve. An example of how multiple sectors may be intertwined in an energy transition is that of "sector coupling", which means to directly couple the power sector to transport, industry and buildings as a way of electrifying these sectors, as a pathway to decarbonization (Bloomberg Finance L.P 2020). The background for suggesting this type of coupling is because of the interlinkages between sectors and systems that have the potential to decarbonize, and that changes in one sector necessarily will affect another (Rosenbloom 2019). This means that one could argue that grand challenges such as climate change should be tackled through multi-sector interactions because of these interlinkages, a view that has become an emerging agenda within the research field of sustainability transitions (Andersen et al. 2020; Markard 2018).

Sustainability transitions is an established research field, which have become increasingly relevant the past ten years, with international research networks and peer reviewed journals (Köhler et al.

2019). This field have roots in innovations studies, and attempts to uncover how and under what conditions system change towards sustainability come about (Köhler et al. 2019; Markard, Raven, and Truffer 2012a). The research field provides theoretical frameworks and concepts that contribute to understanding these transition dynamics, and how changes come about in systems consisting of all types of actors and stakeholders, technologies, and values and beliefs (Markard et al. 2012a). Also, increasingly, scholars acknowledge how sectors rarely act alone and may have limited impact alone, but that they interact and affect other sectors or systems, as substantiated by real life cases of transitions (Andersen et al. 2020; Fischer and Newig 2016; Rosenbloom 2019, 2020). These, and other ideas from the field of sustainability transitions are useful for gaining an understanding of these processes.

As some scholars from the transitions field have addressed, the focus on actors in transitions research is somewhat underdeveloped, as popular frameworks are more concerned with system level dynamics (Farla et al. 2012a; Markard et al. 2012a). This points to a research gap in addressing actor roles and their importance in sustainability transitions. This include a lack of research on actor roles, in addition to interactions between them and how they coordinate their actions as the transition unfolds (Farla et al. 2012a:996). Thus, this calls for increased attention to actor roles and interactions in research on transition. Second, there is an emerged agenda for researching multi-sector dynamics, based on the proposition that transitions rarely only involve a single sector (Andersen et al. 2020; Rosenbloom 2019). These multi-sector dynamics involves interaction between multiple sectors, and linkages between actors across sectors. Thus, the lack of actor perspective in transition studies, and the call for increased attention to multi-system interactions constitute a research gap. Addressing these two dimensions of sustainability transitions may contribute to the research, focusing on actor-level aspects in the context of multi-system interactions.

RQ: How are actor roles and actor interactions shaped in cross-sectoral sustainability experiments?

This thesis seeks to investigate actors in transitions where multiple sectors intersect. The topics of interest regarding actors is how actor roles are shaped within sustainability experiments that goes across sectors. In addition to looking into actor roles, the topic of interest is how actor interaction s between multi-sector actors are shaped in these experiments.

When different sectors intersect in sustainability transitions, actors from different social realms take upon different roles, and actor networks and challenge-led initiatives are formed. Public authorities often take a leading role in shaping transitions and subsidizing pilot projects for sustainability, and private companies also take various roles. What happens when actors from these two spheres come together in projects with the aim of achieving increased sustainability gains, and how are the roles allocated between the actors participating in such projects? This thesis seeks to investigate how actor roles are shaped and potentially change in sustainability experiments with participants from multiple sectors. Additionally, the topic of interest revolves around how actor interactions are shaped in such experiments.

1.2. Electrification of Construction Sites

The field of sustainability transitions as an emerging field has gained momentum due to the increased focus on climate change, and the emergence of new, technological solutions to promote sustainability. What is commonly referred to as the "energy transition" is pointed to as one of the most important ways to reduce global carbon emissions, as large amounts of the energy use today comes from fossil energy sources. Further, a pathway towards decarbonization involve electrification of transport, buildings, and industry sectors, there are reports released going into depth on how much emissions that could be reduced if these sectors were to shift from fossil fuels to renewable energy sources (Bloomberg Finance L.P 2020). The building-, and construction sector in Norway was in 2020 responsible for about 2 million tons of Co2 in direct emission,

meaning that there is a potential for substantial cuts in this sector (Statistics Norway [SSB], 2020). The decarbonization pathway of electrification could contribute to reducing substantial parts of these emission. Public authorities are looking for solutions and measures for reducing national and regional emissions, and in the past years, increased attention has been paid to the potential of electrifying the building-, and construction sector (Norwegian Government 2021). Among other, municipalities have formulated climate goals specifically targeting reduction of emissions from building-, and construction sites. As a measure for reaching these set targets, various pilot projects have been initiated, in addition to the creation of subsidy programs from the business support system (ENOVA 2021). What have been depicted as Norway's, and even the world's first zero emission construction site was conducted in 2019, using electrical machinery as a substitute for machines that run on diesel (Fossheim 2019). This pilot project, however, have only been the beginning of projects and initiatives aimed at testing electrical machinery at construction sites, and an increasing number of firms and public authorities look at this as a promising pathway towards emission reductions, and engage in activities aimed at supporting this *electrification of construction sites* (ENOVA 2018). These activities often take the form of pilot projects involving multiple actors attempting to test and develop solutions through problem-solving and learning activities with the aim to test and develop the technological solutions (ENOVA 2021).

This electrification process can be viewed as a sustainability transition in a phase where piloting and experimenting is being conducted to increase learning and help with market creation, and the initial case research uncovered that a multitude of cross-sector actors are involved in such experimental projects. With this background, this case is fitting for answering the research question regarding role of actors in experiments for sustainability, and role of collective action.

Several improvements regarding heating and use of buildings have been made to make the construction industry more sustainable, but there are still substantial emissions coming from the construction phase of a buildings life, which in Oslo accounts for 7% of total emissions (Omland 2019). These emissions come from fossil-fueled diggers and other machines on the site. Several pilot projects and research and development initiatives have been conducted to help the industry

transition from use of fossil-fueled machines used on construction sites towards zero-emission technologies, resulting in what is thought to be the world's first all zero-emission construction site in Oslo in 2019 (Fossheim 2019). This was a result of initiatives from Oslo Municipality and public support, and a part of their climate strategy, as they have decided that all of their own building and construction projects should be zero emission within 2025. Trials and pilots such as this are important for learning and developing solutions, but there is still a long way to go due to immature markets, technologies, infrastructure, and high costs. Through reading a selection of the media content and other reports on the topic of zero emission construction sites and related topics, it becomes apparent that there is an increase in development of zero emission technologies on construction sites, and many predict that use of electric, electric-battery and machines on hydrogen will become the dominant technologies in the future's building and construction industry. There is, however, barriers that prevent the diffusion of such zero-emission technologies. Among these are immature market and technology development, and high initial investment costs. The market for electric machinery is still small, both with a lack of availability and demand, which in turn makes the purchase of these machines expensive for contractors. Higher demand would lead to the possibility to produce more machines at a lower cost and increase availability of machines, making it affordable for contractors and builders. Therefore, the actors involved in such projects points to public procurement as an important tool to increase demand and help the industry transitioning faster. Accordingly, different municipalities are in the process of requiring zero emission or fossil-free technologies on their own building projects, as Oslo Municipality already have. There is, however, ongoing discussions on whether the "Planning and Building Act" makes room for implementing these climate requirements on projects in the private market, as is desired by advocates of zero emission construction sites (Norwegian Government 2021). The current situation of zero emission construction sites in Norway is still dominated by trials and testing of new or improved technological solutions to solve issues on providing the energy required on the construction site. Additionally, there is also the issue that the grid infrastructure is not ready to provide the amount of energy needed to electrify all construction activities in Norway.

In this thesis, the case of electrification of building-, and construction sites in Norway will be used to provide insight on actor roles and interactions in cross-sectoral sustainability experiments, and

thus expanding on existing research concerned with actor-level dynamics across sectors. There are various types of projects within the case of electrification of building-, and construction sites in Norway. However, distinguishing between the different technological solutions is out the scope of this thesis. The population are market-, or public actors participating in initiatives for testing electrical machinery and related technologies at construction sites, both including building and construction. Following, the terms “construction site” and “building-, and construction site” will be used interchangeably. In the cases where the data material strictly distinguishes between experiences with electrification of buildings or other type of projects specifically, this will be specified. Further, the term “zero emission construction site” is the buzzword in the industry and political environment, as the main goal is reducing emissions from the construction processes, not necessarily through electrification (Research Council 2019). However, uncovered by the preliminary research on this topic, other types of solutions, such as hydrogen, have yet to appear in the market, meaning that for now, solutions using electricity are the prevailing technologies. It is also important to note that ambitions on fossil-free construction sites are also goals articulated by municipalities. This aspect, however relevant, will not be carefully discussed in this research.

1.3. Structure of Thesis

This thesis is structured as followed:

Chapter 1: Provides a presentation of the theoretical problem from which the research question is derived, and states social relevance of the research project.

Chapter 2: Include a description of the theoretical basis for the thesis, and concepts and theories used in the analysis.

Chapter 3: The methodological chapter which include a description of the research design, execution, and considerations of research quality and ethics.

Chapter 4: Presentation of empirical findings and analysis.

Chapter 5: Discussion of findings in relation to the research question and theoretical background.

Chapter 6: Concluding remarks including main contribution to research, strengths and weaknesses of research, and implications for further research

Finally, the reference list and appendixes are included.

2. THEORETICAL FRAMEWORK

This chapter of the thesis will provide a theoretical toolbox for analyzing the empirical case and answering the research questions, including both a depiction of the research area and related literature, in addition to a selection of concepts and frameworks that will form the theoretical basis of the analysis. The first section will present the field of sustainability transitions and common concepts, which constitutes the theoretical universe this thesis belongs to. I will also elaborate on what parts of the field have been selected and why, in addition to presenting some relevant research debates within the field.

To answer the research questions regarding the role of sustainability experiments and actor interactions in sustainability transitions, an analysis will be conducted within the sustainability transitions literature which have emerged from the field of innovation studies, in addition to complementary literature from organizational studies. First, the decision to use literature on sustainability transitions in this thesis is that it provides a selection of tools and frameworks for analyzing transition phenomena, as the field emerged specifically with the agenda to provide a space for scholars to research shifts in social and economic environments towards sustainability (Köhler et al. 2019; Markard et al. 2012a). Some of these concepts include the commonly accepted idea of socio-technical systems, and how transitions towards sustainability come about.

Nevertheless, gaining an understanding of the context these actors operate within is useful as context may provide constraints or opportunities for actors. Systemic aspects that affect actor behavior will thus be utilized, using the idea of socio-technical systems (Rosenbloom 2019). This will be done by introducing concepts that may help explain how different socio-technical systems and the actors within them interact, as they become intertwined due to decarbonization pathways (Rosenbloom 2019). After establishing this theoretical context where the actor and interactions among them happen, a brief explanation of sustainability experiments will be provided. Experimentation is often discussed in transitions literature, as an important step for learning in

developing new innovation (Smith and Raven 2012; Sengers, Wieczorek, and Raven 2019). As the main objective of this thesis is looking at actor roles, a typology of actors and their functions will be provided, which is derived from literature reviews of transitions literature (Farla et al. 2012a; Fischer and Newig 2016). Lastly, some theoretical aspects of actor interactions and collective action will be presented, combining insight from transition studies and organizational studies, which have a longer tradition of investigating interactions and networks of actors in experiments and projects (Fischer and Newig 2016; Quélin, Kivleniece, and Lazzarini 2017; Selsky and Parker 2005)

The figure below is a depiction of the logic of this theory chapter, presenting a summary of the theoretical concepts that will be used to analyze case.

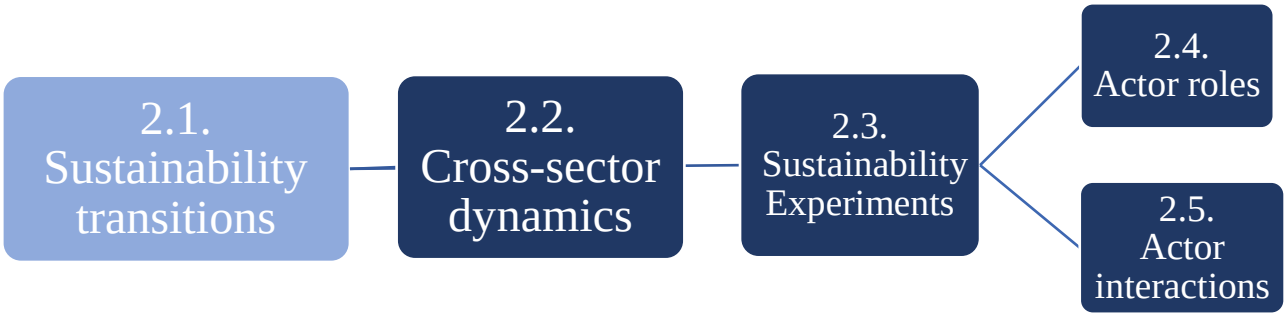

FIGURE 1: SUMMARY OF THEORETICAL FOUNDATION

2.1. Sustainability Transitions

Theoretically, this thesis is grounded in the field of sustainability transitions, which has gained growing attention in academic fields over the past 20 years, a field that have emerged from the field of innovation studies (Markard, Raven, and Truffer 2012b:955). A benefit of using

frameworks from an innovation studies perspective is that it draws analytical attention to novelty and the role of existing structures (Smith, Voß, and Grin 2010).

The field of sustainability transitions emerged as a response to the grand sustainability challenges such as climate change and provides useful concepts for analyzing the process of societal and technological change towards sustainability. This field is appropriate to consult when discussing these processes, as it considers the political and economic context of these changes, and acknowledges the role of technologies, various actors, and changes in values and beliefs in the society (Köhler et al. 2019; Markard et al. 2012a:955). Thus, to research phenomena relating to changes towards a more sustainable society, searching for theoretical foundations within the sustainability transitions field is appropriate. What follows is a depiction of how scholars from this field defines *sustainability transitions* and some characteristics they possess. Lastly, a brief introduction of common frameworks and research strands within the field will be presented, followed by an elucidation of the decision to draw on the literature on multi-system interactions in this thesis (Andersen et al. 2020; Rosenbloom 2019, 2020).

As the field of sustainability transitions field are relatively novel, it is constantly changing, and there exist many different branches and discourses. Common for most transition scholars, however, is the idea of socio-technical systems, which entails a conceptualization of sectors such as the energy sector and transportation. These socio-technical systems consist of a configuration of elements such as networks of actors, markets, policies, institutions, material artefacts and knowledge (Geels 2002; Köhler et al. 2019:2; Markard et al. 2012a:956). A sustainability transition involves a shift in existing structures in a system, often involving a degree of novel technologies or processes, a reconfiguration of the elements which include changes in both technologies, institutional frameworks, markets, and cultural beliefs (Laakso et al. 2021; Markard et al. 2012a). Thus, a sustainability transition refers to a shift leading to more sustainable configuration in these socio-technical systems.

Sustainability transition is thought to have various characteristics in addition to involving a shift in existing structures, which are useful to have in mind when researching the phenomena. First, sustainability transitions are defined as long-term, fundamental transformation processes that require co-evolutionary change processes (Geels and Schot 2010; Köhler et al. 2019; Markard et al. 2012b). Second, there is an assumption that transitions are multi-actor processes that include actor groups such as academia, civil society, politics and industry, actors that all have their own set of capabilities and resources (Köhler et al. 2019:2). Third, Köhler and colleagues discuss how transitions have a high degree of contestation, uncertainty and open-endedness (Köhler et al. 2019:2,3). These characteristics substantiate the claim that sustainability transitions are complex change processes which involves a broad specter of actors and interactions across a multitude of dimensions.

Within the sustainability transitions field, there are four approaches that have become particularly prominent. The *Multi-Level Perspective* on transitions is highly rooted in the field of innovation studies and ideas from the sociology of technologies and evolutionary economics (Geels 2002; Smith et al. 2010). The idea behind this view is that socio-technical systems consist of three distinct levels, where the socio-technical regime is the space where existing structures are withheld, socio-technical landscape is the level where cultural beliefs are, and socio-technical niches is where radical innovations emerge, often with the intention of challenging the existing structures of the regime and drive change processes (Geels 2002; Frank W Geels 2014; Geels 2019). Another prominent theoretical framework is *Technological Innovation Systems*, which propose that successful development of a technology depend on seven functions (Jacobsson and Bergek 2011). These include knowledge diffusion, experimentation, influence on the search direction, formation of market, legitimation, legitimation, resource mobilization and positive externalities (Jacobsson and Bergek 2011; Köhler et al. 2019:4). Third, Transition Management revolves around the idea that transitions can be governed through policymaking, as following the four steps of conducting strategic activities, tactical activities, operational activities, and reflexive activities (Kemp, Loorbach, and Rotmans 2007). The fourth influential research strand in sustainability transitions are *Strategic Niche Management*, highlighting how radical innovation emerge in spaces protected from market selection (Köhler et al. 2019). These innovations are in this view usually being

developed by new entrants in the market or industry, and experimentational learning is an important tool for the development of niche-innovations (Geels and Raven 2006; Köhler et al. 2019:5).

These four research strands and frameworks all provide useful insights for analyzing transitions, however, there are some aspects of transitions they do not engage with that thoroughly. Among other, some scholars have pointed out that these frameworks highlight change dynamics within single sectors, at the expense of researching the role of cross-sector interactions in transitions (Andersen et al. 2020; Rosenbloom 2019, 2020). Thus, when investigating aspects on cross-sector interactions, and experiments engaging actors from multiple sectors, these theoretical frameworks are less powerful.

In addition to these four main theoretical foundations, transition studies provide a variety of concept useful when analyzing a transition or similar change dynamics, which will be presented in the following sections. Even as this thesis don't use these four conceptual frameworks in the analysis, the underlying idea of socio-technical systems will be used to help point to the social, economic and political context actors operate within. A further description of socio-technical systems and how interactions between them affect actor-level dynamics are provided in the next section.

2.2. Cross-Sector Dynamics

As stated in the previous section, the most prominent frameworks of sustainability transitions, however useful, is lacking tools for analyzing cross-sector dynamics and its importance in transitions. Thus, as a way of expanding on the existing research agenda within the field, scholars are shifting their attention towards a multi-system perspective, acknowledging that transitions rarely are single-sector phenomena (Andersen et al. 2020; Rosenbloom 2019, 2020). This perspective aims at zooming out from the sector-level dynamics, researching how these transformational processes affect, and are affected by other adjacent sectors than where the

transition emerges from (Rosenbloom 2019, 2020). Additionally, some scholars argue that when researching transitions as they move towards a diffusion and acceleration phase, these cross-sectoral dynamics become increasingly important (Markard 2018). Jochen Markard distinguishes between the first and second stage of transitions, where the first phase is characterized by the emergence of new technologies, immature markets and public support towards a second phase involving diffusion and acceleration, the broader context and adjacent sectors are increasingly affected (Markard 2018). This view further substantiates the need for increased attention to multi-sector dynamics.

This increased attention to how multiple sectors are intertwined in transitions have resulted in the formation of a multi-system perspective, which is a relatively novel research strand in the sustainability transitions field. This thesis seeks to investigate aspects regarding actors and cross-sector sustainability experiments. Thus, drawing on this multi-system perspective may contribute to providing a better understanding of the context that shape actor interactions and linkages across sectors.

The multi-system perspective draws on the conceptualization of sectors as socio-technical systems, consisting of a set of actors, infrastructures, technologies, markets and governance (Rosenbloom 2019:220). These different socio-technical systems are thought to become increasingly intertwined in decarbonization pathways where multiple sectors are involved. Actors from these different sectors interact at the interface of these systems, in what Rosenbloom describe as *sites of interaction* (Rosenbloom 2019). The figure below is a representation of first, how systems interact and create new couplings through *sites of interaction* to fulfill a societal function, and second, how these interactions become either symbiotic or competitive (Rosenbloom 2019:221).

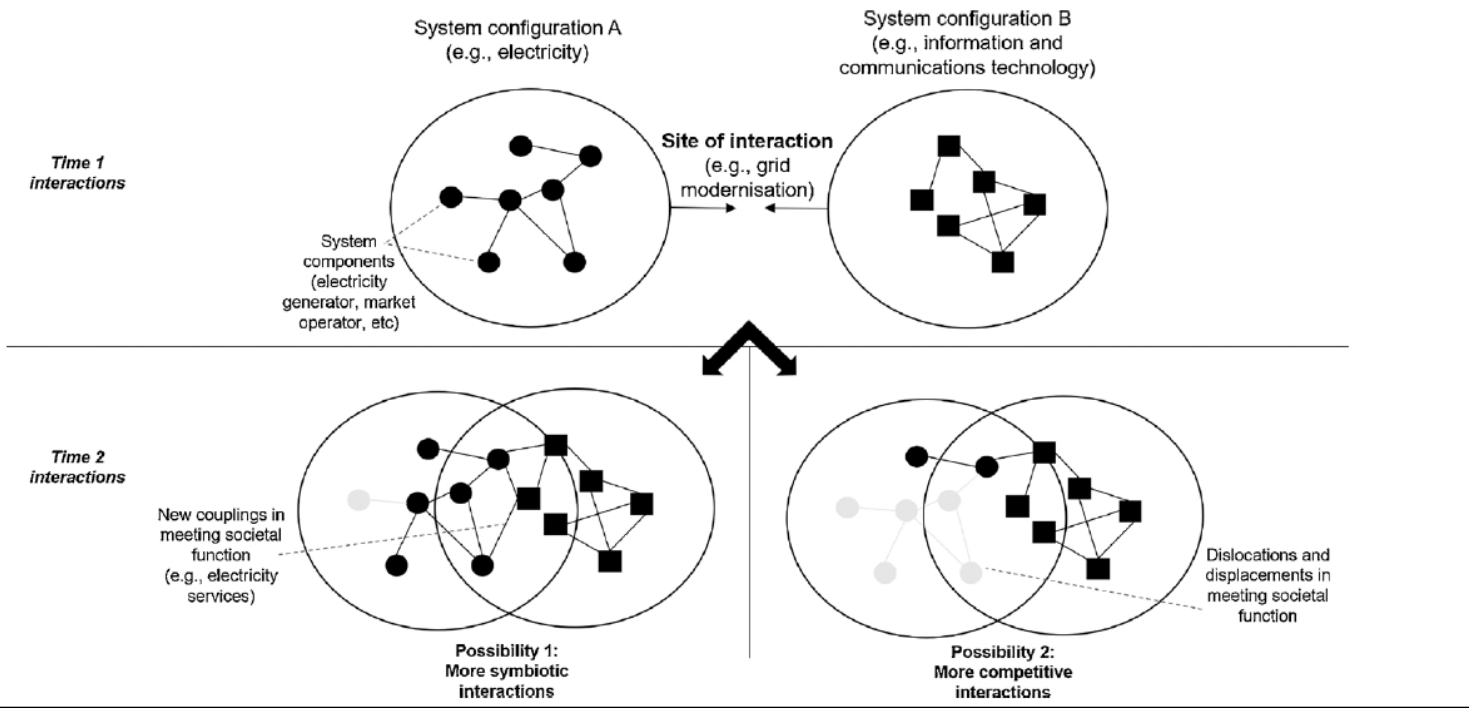

FIGURE 2: A MODEL OF SYSTEM INTERACTIONS, ROSENBLOOM 2019

As highlighted in this model, new couplings emerge because of this site of interaction, linkages that among other are shaped by policy interventions, new innovations and actor networks (Rosenbloom 2020:338).

In addition to assessing new sites of interaction, Rosenbloom argue that the multi-system perspective should seek to investigate both existing linkages between systems, and how interaction patterns may change over time (Rosenbloom 2019:338). In this thesis, some attention will be paid to existing linkages between the systems of interest, but then as a way of comparing the old to the new linkages which emerge because of the new interaction site of experiments for electrification of construction sites.

Following, the main concepts and ideas to be derived from the research strand of multi-system interactions is how new site of interaction lead to new linkages between actors from different sectors (Rosenbloom 2019, 2020). Further, the complexity of transitions and embeddedness in

multiple systems results in increasing need for interaction across them. This interaction happens in *sites of interaction,* which is spaces where often new cross-sector actor linkages emerge. It should also be noted how these new linkages or couplings are shaped by among other, policy interventions, new innovations and actor networks (Rosenbloom 2020:338). When attempting to answer the question of how actor interactions are shaped in cross-sectoral sustainability experiments, the view of multi-system interaction will contribute with understanding of the context in which these cross-sectoral interactions happen.

2.3. Experimentation for Sustainability

In the last section, the idea of "sites of interaction" between sectors was introduced, referring to the spaces where actors from these sectors. An experiment involving multiple actors across sectors, or systems, becomes a natural space for interacting and create new linkages or networks, meaning that such a project can be described as an *interaction site*. This thesis seeks to research aspect around cross-sectoral experiments aimed at promoting sustainability, and thus, having a clear idea of what an experiment entail is important. This section provides an explanation of how transition scholars use this term, and how it will be used specifically in this thesis.

Experiments such as testing new technologies or pilot projects is considered a key agent for change in the field of Sustainability transitions (Sengers et al. 2019:153). As piloting and testing new, relatively disruptive innovations is pointed to as means to achieve reduced carbon emissions and deep decarbonization, having a clear idea of what this entails is useful. Experimentation for sustainability transitions in the context of welfare states have been discussed by various transition scholars, which is explained as experiments conducted in a real-life societal context, and that the goal of experimenting is to achieve changes in the "social and material realities" (Sengers et al. 2019:154). Experiments in this context have been given different terms based on the characteristics of the experiment and theoretical discourse it emerged from, and includes socio-technical-, grassroot-, transition-, niche-, and sustainability experiments (Sengers et al. 2019). There exists some overlap between these experimentation types, but to answer the research question of how

actor roles emerge and adapt through experimental projects for sustainability, the *sustainability experiment* type seems most applicable as theoretical concept. Sustainability experiments are defined as planned, or non-accidental, and aims to tests new, radical solutions, that eventually lead to high sustainability gains such as emission reduction (Sengers et al. 2019:158). Further, the idea is that the activities are executed in "sites of experimental learning", where the actors involved may build on existing knowledge and experiment for new knowledge in a learning space where the outcome is unknown (Sengers et al. 2019:161). This approach and role of experiments enhances the practice-based nature of sustainability transitions literature.

This concept of experiments for sustainability is well suited for discussing the experimental projects researched in this thesis, as they are defined as challenge-led, practice-based, and engage multiple actors, with learning and problem-solving as main components. This description also aligns with the nature of the pilot projects aimed at transforming the building-, and construction sector, as they too are set in a societal context, performed by real-world actors and are challenge-led. In addition to R&D activities, these pilots involve testing radical technologies on construction sites. Further, these experiments are described as measures for re-shaping material and social realities (Sengers et al. 2019). This is also the aim of the pilot projects for electrification of the construction sites, as they attempt to affect market demand and technology development to achieve the overall goal of reducing carbon emissions in the sector.

2.4. Actor Roles in Sustainability Transitions

One of the main objectives of the research question is investigating actor roles and actor interactions within the specific context of cross-sector sustainability experiments. After establishing the contextual foundation and conceptualization of these experiments, the next step is to discuss actor roles and interactions among them in attempts to fulfill the agenda of experiments. Thus, this section will provide a vocabulary for discussing actors and actor roles, as depicted in sustainability transitions literature, which then will be used to analyze actors roles in cross-sector sustainability experiments.

As stated in the introduction, the emerging field of sustainability transitions have gained some criticism for being too focused on systemic aspects of transitions, at the expense of actor-level aspects (Farla et al. 2012a:996). Other scholars dispute this claim of negligence of actor perspective in the literature, but nevertheless, this criticism have led to increased attention to actors in transition research (Fischer and Newig 2016; Köhler et al. 2019:11). Transition scholars have different ways of including actors in research and theories. Köhler and colleagues state that sustainability transitions are *multi-actor* processes that include actor groups from academia, civil society, politics, and industry (Köhler et al. 2019:2). These different actors have each their capabilities and values, in addition to resources, agendas and strategies (Köhler et al. 2019:2). Further, Frank Geels have developed a framework looking at the role of firms specifically, and how they are embedded in an industry regime, and in the external spheres of economic and socio-political environments (Frank W. Geels 2014a). Further, Farla and colleagues suggest taking a closer look at actors, strategies and resources within the field of sustainability transitions (Farla et al. 2012a). Through a literature review of seven papers, they suggest that actor level and system level processes are highly intertwined, substantiated with findings from empirical research that shows how "*changes in socio-technical systems often are traced back to strategic interventions of particular actors*" (Farla et al. 2012a). Investigating the role of actor-level processes is thus an interesting take that can help gain a deeper understanding of what drives sustainability transition and create system change. Musiolik and colleagues makes the same claim, highlighting the interconnection between system and firm level processes, in addition to discussing the role of innovation networks and collaborating actors in the formation of new technological innovation systems (Musiolik, Markard, and Hekkert 2012).

Whereas there poses some disagreements as to whether actors have been neglected in the transitions literature, there seem to be consensus on the lack of common definition and structure, such as whether it involves organizations, larger social groups or individuals (Fischer and Newig 2016:2). As a response to this deficiency of structured definition of actors, Fischer and Newig presents three typologies of actors and the functions they fill in transitions, derived from their literature review (Fischer and Newig 2016:476). This typology divides actors in the three *social realms* of *civil society*, *market* and *state*. Farla and colleagues use the similar terms *civil society*, *firms*, and *public*

authorities to separate actors in categories (Farla et al. 2012a:995). Following is a presentation of these three actor groups, which include the common characteristics, traditional roles, strategies, resources, and functions in transitions, as uncovered by various transitions literature (Farla et al. 2012b:995; Fischer and Newig 2016:476).

State: Policymakers and public authorities are identified as actors traditionally taking upon the role of supporting new, sustainable technologies before they are competitive in the market, in addition to taking upon the role of enabling experimentation of new technologies (Farla et al. 2012a:995; Foxon, Hammond, and Pearson 2008). However, some research claim that public authorities increasingly take a more active role in transitions through facilitating experimentation and thus enabling innovation and gaining a new role (Fischer and Newig 2016; Foxon et al. 2008; Quitzau, Hoffmann, and Elle 2012). It's important to note, however, that public entities often depend on industry actors and broader society, and thus may be constrained (Farla et al. 2012b).

Firms: Firms can take upon a variety of roles in transition, depending on their strategies, business goals, and other factors (Farla et al. 2012a:995). A number of transitions scholars highlight the resistant strategies and actions of incumbent firms opposing a transition for different reasons (Frank W Geels 2014). The reasons for incumbent firms opposing transitions is often due to lock-ins, such as their economic interests, and embeddedness in existing infrastructures (Seto et al. 2016). This approach highlights how radical innovations and drivers of change emerge with new entrants, challenging the incumbents (Frank W. Geels 2014b; Hockerts and Wüstenhagen 2010). Other scholars challenge this somewhat one-sided depiction of incumbent firms, claiming that incumbent actors can have an active role in developing and promoting radical innovations similar to new entrants creating niches (Turnheim and Sovacool 2020). This approach acknowledge that incumbent firms can actively engage in actions supporting transitions, deliberately creating spaces for development of radical innovations and recruiting collaborators or alliances (Farla et al. 2012b:995). Further, these firms may lead the development of new solutions, either by wanting to diversify their operations or making strategic decisions based on expectations (Foxon et al. 2008:8).

Civil society: The third social realm *civil society* are thought to contribute to transitions through putting pressure on policymakers, or use consumer-power to put pressure on market actors (Fischer and Newig 2016:7).

In discussing actor roles, transition scholars also point to how actors regardless of social realm may have different roles in different phases of a project, substantiated by empirical evidence (Fischer and Newig 2016:476). This change in actor's roles often appear when there is a shift from one phase of a transition to another, or when the mode of a project changes (Bai et al. 2010:320; Kemp, Loorbach, and Rotmans 2007; Köhler et al. 2019). Grin and colleagues make the same claim regarding changing roles over time, and expanding on this view by proposing that the interest and preferences of actors change throughout the transition process (Grin, Rotmans, and Schot 2010). Following these views of changed actor roles over time, it is proposed to research actors in different phases of transition, divided into the four phases predevelopment, takeoff, breakthrough, and stabilization (Avelino and Wittmayer 2016; Fischer and Newig 2016).

In the analysis of actor roles, the notion of how actor roles may change throughout the transition process up until the point of stabilization will be used. Additionally, the typology of actors will be used, as it provides a vocabulary for discussing the role of actors participating in the sustainability experiments. Specifically, the notion of traditional roles of public actors will be addressed. In the analysis, the main emphasis will be on actors from the social realms of *state* and *market*, as the case study conducted in this thesis focus on market actors in addition to public entities, leaving the inclusion of actors from the civil society to another study.

2.5. Actor Interactions

The cross-sectoral sustainability experiments that was presented in section 2.3, can be viewed as an interaction space for actors from across sectors. These interaction sites are spaces where new actor linkages emerge, including linkages between two actors, or larger actor networks. As

previously uncovered by transition scholars, actors rarely act alone and have little impact alone when it comes to sustainability transitions, meaning that actor interactions may be of great importance in transitions (Fischer and Newig 2016). The second part of the research question is concerning how actor interactions are shaped in the context of these interaction spaces, and what it means for sustainability transitions. Investigating aspects around these actor interactions in these spaces of interaction and experimental learning may thus provide useful insight to micro-level dynamics in transitions. In order to discuss this topic in a fruitful way, having a clear understanding of what actor interactions mean is necessary. First, some ways actor interactions have been discussed in the sustainability transitions literature will be presented. Further, as actor-level dynamics in sustainability transitions is a somewhat underdeveloped strand of research, complementary literature from organizational will be introduced, contributing to analysis of actor interaction.

As discussed, there are some discussions on whether the actor perspective has been neglected in transition studies. However, there seem to be consensus that there is a research gap within the field regarding the impact of collective actions and actor networks (Farla et al. 2012a:995). The main emphasis of research discussing actor roles have been on the actions of incumbent firms, new entrants, prime movers, and system builders, and less on the importance of collective actions (Farla et al. 2012a:995; Hockerts and Wüstenhagen 2010). The literature review uncovered that empirical studies show how individual actors rarely act alone, and have limited impact alone in transitions, but that they interact with others across the social realms of state, market and civil society, and depend on other actors (Fischer and Newig 2016). These dependencies call for collective action, collaborations, or formation of networks across social sectors to achieve successful sustainability transitions. The research gap of collective actions in transitions motivated looking closer at this aspect in this thesis. Following is a presentation of how existing transitions literature discuss collective action, or collaboration, followed by discussions from organizational studies, as this field a longer tradition of researching actor interactions and collaboration.

Fischer and Newig state that networks of firms may positively contribute to transitions through the development of necessary information channels, and claim that these connections may be of great

importance when the functions and roles of actors change (Fischer and Newig 2016:476). Empirical evidence have shown that the roles of actors change over time, often when a transition move from one phase to another, creating room for different distribution of roles and a change in functions that are necessary to fill (Bai et al. 2010; Fischer and Newig 2016:12). This insight help substantiate the importance of actors coming together and how different stages of a transition may require interaction among participating actors to change.

This thesis attempts to point to aspects of actor interactions in sustainability experiments bringing actors from multiple sectors together. The scholars from the field of sustainability transitions, however, point to a research gap in research on these types of actor networks or collective action for sustainability (Farla et al. 2012a:995). Thus, complementing with literature from organizational studies may be source of contribution. The organizational studies literature on actors are substantial, all of which will not be consulted in this thesis. Within the field, there have emerged a strand of research focusing on challenge-led collaborative initiatives aiming at creating sustainability gains (Quélin et al. 2017; Selsky and Parker 2005). This literature will be used to complement the research form sustainability transitions, as the cross-sectoral experiments can be viewed as such collaborative initiatives.

In the actor typology discussed in the previous section, actors belong to one of the three social realms of civil society, market, and public sector. The organizational literature on constellations of firms working together for sustainability draw on similar arguments, proposing that such actor networks or partnerships often are *hybrid arrangements,* consisting of actors from the three social realms (Quélin et al. 2017; Selsky and Parker 2005). Organization scholars define these actor constellations or collaborations as project-based, temporary, and with the main activities engaging in problem-solving, resource allocation and information sharing (Klitsie, Ansari, and Volberda 2018; Selsky and Parker 2005). Selsky and Parker discuss how project-based actor networks to address social issues bring together a variety of actors with the common goal of creating sustainability gains. Additionally, the scholars highlight how these types of collaborations often seek to address wicked problems, such as sustainability issues, and that even as the collaborations are temporary, the main goal is to create long-term change (Klitsie et al. 2018; Manning and

Roessler 2013). This view is applicable when discussing sustainability experiments, as these experiment share the same characteristics of bringing together multiple actors, being temporary and project-based, and oriented towards creating sustainability goals (Sengers et al. 2019). Further, this view of *hybrid arrangements* for contribute with increased focus on the collaborative and interactive aspects of such projects or experiments. In addition, Selsky and Parker discuss how these collaborative actor networks may lead actors to take upon untraditional roles in the projects, which is explained by this problem-solving (Selsky and Parker 2005).

These ideas of collective action will be used in the analysis, as it provides additional vocabulary to discuss interactions between actors, which in this project revolved around actors from multiple systems that establish contact through sites of interaction (Rosenbloom, 2019, 2020).

2.6. Chapter Summary

In this chapter, different views of transitions and actors have been thoroughly examined, some of which will be used to analyze the empirical case of electrification of construction sites and answering the research questions. The conceptualization of sectors as systems which consists of different elements, and how these different systems interact form the core systemic context in which the actors operate within. This view will be used to highlight how this context shape interactions between actors from different sectors involved in electrification projects. It also helps create a vocabulary to discuss the interaction spaces in which cross-sector interactions happen. The "site of interaction" in this study is sustainability experiments, as these experiments or projects creates the space in which the cross-sector actors interact. Further, to get to the core of the research questions regarding actors and interactions among them, a vocabulary of who the actors are, and what functions or roles they take upon in experiments for sustainability transitions will be proved useful, in addition to aspects of actor interactions. As empirical studies from transitions research show that actors rarely act alone, but interact with other across *social realms*, the issue of collective action will be investigated within the context of system interaction, or across social realms.

3. METHODOLOGICAL APPROACH

To answer the research question regarding how actor roles and interactions are shapes in cross-sectoral sustainability experiment, an embedded single-case study was conducted, using semi-structured interviews and documentation as source of information. This chapter discuss the methodological choices of this thesis, data collection process, addressing how to ensure the quality of the research, in addition to ethical considerations.

3.1. Social Science Research and Qualitative Methods

In social science research, the aim is to through empirical research gain knowledge on the social reality through collection of data that are analyzed and interpreted (Johannessen, Tufte, and Christoffersen 2010:31). Within these research methods, a distinction is made between qualitative and quantitative research methods, where the former is characterized by collecting statistical data to map the regularity or results of human phenomena (Johannessen et al. 2010:32). Qualitative methods, however, are used to detect human experiences and are the chosen path for the study in this thesis (Johannessen et al. 2010). Qualitative methods are also preferred when the aim is to study phenomena that we want to understand more thoroughly and know little about in advance (Johannessen et al. 2010:32). Regarding cross-sector collaborative projects for sustainability, there are likely many interesting findings to be uncovered using quantitative methods, such as how impactful these projects are at promoting sustainability, how many of these projects are successful and so forth. However, the main objective in this study is concerning special characteristics of the actors in these projects, and *how* they attempt to contribute to the green shift in the building-, and construction sector. Further, as the specific empirical case of electrification of construction is a

relatively new phenomenon that we have little knowledge on, qualitative methods seem most fitting.

3.2. Case Study Research

Among the qualitative research methods, we find ethnography, grounded theory, phenomenology and case study research (Johannessen, Tufte and Christoffersen, 2010). To answer the research question presented in the introduction, a case study was conducted, as it is a method well suited for researching temporary phenomena within a real-life context, and when the intent is to ask and attempt answering "why" and "how" questions (Yin, 2009, p. 2). Case study research can be conducted using both qualitative and quantitative methods of analysis, and is a commonly used research design in social science research (Gerring 2008:10). Some strengths of case study research are how they provide detailed information, and may give insight to further research (Yin 2009). Critique of case study research revolves around the issue of bias, lack of rigor and difficulties in generalizing for a broader population (Yin 2009:14). Most of these issues, however, may be mitigated by doing thorough and systematic work in the planning and processing of data material and evidence (Yin 2009). The issue of generalizability, however, should always be discussed seriously. Yin proposes that case studies are not suited for generalizing for a broader population, but rather for making theoretical propositions (Yin 2009:15). The research questions of this thesis are derived from a theoretical problem based on real-life cases but rooted in the research field of sustainability transitions. The claim that case study research can "expand and generalize theories" substantiate the decision to take upon the challenge to conduct a case study in this research project (Yin 2009:15).

There are multiple ways of designing a case study research, and the nature of the empirical case chosen shaped the direction of this research design. Yin depicts five important components of research design, including (1) the study question, (2) propositions, (3) its units of analysis, (4) the logic linking the data to the propositions, and (5) criteria for interpretation (Yin 2009:27). This list of components was used as a checklist for ensuring the quality of the research design.

3.2.1. Defining the case

The case study design is an embedded single-case study, as the decision was to look at projects for electrification of construction sites in Norway as the general population. Yin propose five rationales for choosing to conduct a single-case study, where one entails that the researcher have possibility to investigate an unique case (Yin 2009:43). The case of electrification is an ongoing phenomena and can be argued to be a unique case in Norway. As the aim of this project is understanding actor roles and interactions, the units of analysis were decided on actors involved in at least one cross-sectoral project testing electrical machinery at construction site. Initially, the case of electrification of construction site in Norway seemed rather comprehensible involving few actors and projects where testing electrical machinery was conducted. However, the case is evolving fast, and during the preliminary research, it became apparent that it involved substantially more actors than first detected. Thus, the units of analysis were chosen partially based on what actors seemed to be the most involved in experiments for electrification of construction based on the preliminary research, and partially based on which of these actors I was able to reach. The final units of analysis ended up being actors currently or previously involved in pilot projects in two large Norwegian municipalities. Below is a figurative presentation of the case and its embedded units of analysis. As the actors most involved in the electrification projects were identified of coming from market and public sectors, actors from these two social realms became the units of analysis.

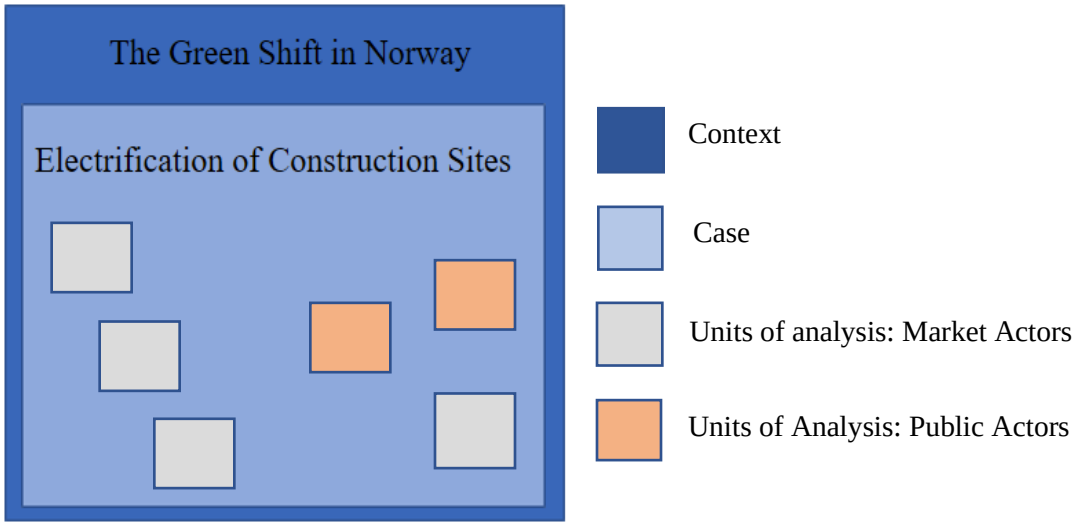

FIGURE 3: MODEL OF THE CASE AND UNITS OF ANALYSIS, ADAPTED FROM YIN 2009:46

3.3. Strategy for Data Collection

The most common sources of evidence or types of data to collect when doing a case study research are archival records, physical artefacts, documentation, interviews, direct observations, and participant-observations (Yin 2009:101). Yin argue that using multiple sources of evidence will strengthen the case study and lead to more convincing conclusions (Yin 2009:116). In this research project, the decision landed on the use documentation and interviews as sources of evidence. The reason for choosing not to do observations is because of time-constraints and the nature of the empirical case as construction projects usually run over multiple years. Regarding archival records or other types of sources of information, as the empirical case are relatively new, not much other data exist.

The decision to use documents as source of information was due to various reasons. First, documents such as media articles and reports about the case was easily accessible through the internet. Second, these types of documents provided useful insight to an industry I was not very

familiar with prior to the research, and thus doing preliminary research through reading documents was important for learning about the case of electrification of construction, and identify relevant actors, organizations and projects. Using documentation for preliminary research was thus important for identifying and limiting the case and provided information on potential informants. Yin state that doing systematic review of documents is important in data collection (Yin 2009:105). Thus, doing a structured media search resulted in a database consisting of relevant news articles and reports.

Conducting semi-structured interviews was chosen as a part of the data collection process, as interviews as source of information is suited when the aim is to gain understanding of people's experiences and thoughts on a topic (Brinkmann and Kvale 2015). As the research question seeks to investigate aspects on actor roles and interactions, gaining the first-hand experiences of the actors participating in electrification experiments were expected to help answer the research questions.

The sampling process of informants begun with the preliminary research on the case of electrification of construction. The research provided information on actors involved in projects aimed at testing electrical machinery at construction sites, and key actors was identified, mostly through media articles. The aim was to conduct interviews with actors from different sectors, as multi-sector interaction was one of the topics of interest. Further, the sampling was shaped by who responded to the request about participating in the research project. Sampling of informants were also shaped by the interest in actors from the three sectors that were identified as most involved in the experiments, so ensuring informant from both the building-, and construction sector, energy sector and public sector was important for answering the research questions. The final list of informants is shown in the table below.

.

Informant	Actor type	Sector	Time
A	Machine Supplier	Building and Construction	75 Min
B	Rental Services Company	Building and Construction	45 Min
C	Contractor 1 (Joint interview)	Building and Construction	60 Min
D	Contractor 1 (Joint interview)	Building and Construction	60 Min
F	Electricity Company	Electricity	60 Min
G	Municipality 1	Public	60 Min
H	Municipality 2	Public	60 Min

TABLE 1: MODEL OF THE CASE AND UNITS OF ANALYSIS, ADAPTED FROM YIN 2009:46

The aim was conducting thematic analysis of the data material, meaning that some preliminary defined themes connected to the research questions would shape the direction of what aspects would be considered most important (Brinkmann and Kvale 2015:133). This approach was followed throughout the process, shaping both the development of an interview guide, in addition to the coding and analysis process. When planning the interviews, the topics of interest shaped the interview guide thematically. The research project is concerned with actor interactions and roles, in addition to aspects of cross-sectoral dynamics. Thus, the overall themes incorporated in the interview guide were (1) the actor's role in the projects, (2) aspects around interactions with collaborative partners in the project, (3) general questions on drivers and barriers of the use of electrical machinery at construction sites. The reason for including questions on drivers and barriers was in order to get the conversation flowing and to learn more about the case. From these themes, specific questions were developed, and as the informants were identified as having different roles in such projects and coming from different sectors, the interview guide was adapted for each informant. The general guide from which these were developed is added as an appendix.

The semi-structured interviews were conducted digitally in the applications Zoom and Microsoft Teams, and were digitally recorded. Before each interview, informed consent was gathered, meaning that the informants were given written information about their rights and how the data would be handled. The same information was repeated in the beginning of each interview, in addition to a thorough presentation of the research project. The topics discussed in the interviews were formulated in the interview guide which was adapted to each informant as they all had different roles in the electrification projects and coming from different types of organizations. However, as the interviews were semi-structured, meaning that due to follow-up questions and somewhat loose structure. This meant that the conversations could deviate from the themes that shaped the interview guide. The experience from the interviews was that these deviations from preliminary decided topics happened quite often, leading to interesting digressions providing insightful statements that might have been lost in a strict structured interview.

3.4. Analyzing the Data

Regarding language, the data collection from the case of electrification of construction in Norway have mainly been in Norwegian. Thus, some any direct quotes used in this thesis have been translated from Norwegian to English. This wase done as carefully as possible, to ensure the true meaning was not lost in translation.

3.4.1. Transcribing

After each interview was conducted and recorded, the next step was transcribing. The transcription was done manually in Nvivo 12, where time stamps were added to make it easier to go back if necessary. When transcribing, the names of persons were left out to protect their privacy, but names of organizations mentioned were included, because they were concluded to be important for the meaning.

Transcribing interviews involve translating from oral to written language, which mean that some interpretive issues may emerge (Brinkmann and Kvale 2015:207). Among other, these issues can emerge a as it can be difficult to know when one sentence stop and another begin. Additionally, humor, body language and tone of voice may have implications for the meaning in conversation, and may become lost in translation to written language (Brinkmann and Kvale 2015). Ensuring good quality of the recording was thus important, to mitigate unnecessary difficulty in translation. Further, as the interviews were both conducted, transcribed and analyzed by the same person, one could argue that less of the true meaning of the will be lost in translation. The weakness, however, of one single transcriber, is due to the interpretive nature of the activity. One of the tactics used for mitigating the issue of interpretive misunderstandings was to through the interview, often repeat statements made by the informant, asking if the interpretation of the meaning was correct. Thus, the informant could either agree or elaborate on the true meaning.

3.4.2. Coding and Analysis

The coding of the data material was done in NVivo. The coding was conducted with a combination of deductive and inductive process. Deductive coding mean actively looking for data related to the preliminary defined themes that was expected to help answer the research questions (Brinkmann and Kvale 2015). These themes were identified as *actor roles*, *experiments*, *system interaction*, and *collective action and interactions*. When coding using these themes, subcategories was developed for a more detailed coding book and to make it easier looking for patterns in the analysis. In addition, an inductive coding process was done simultaneous to the deductive coding, to look for other themes that might emerge. Among other, the themes that emerged from this inductive process helped gain further insight on the case, and the dynamics shaping market creation and technological development. The complete coding book is included as Appendix B.

The coding of the data material was done through a simultaneous process of deductive and inductive coding. Prior to the interview process, four main themes were identified, shaping the

interview guide. Consequently, these themes were deductively coded as findings related to these topics were expected to be found in the data material. During the coding process, however, subthemes were identified and added to the coding book. Additionally, during the coding process, any other interesting or unexpected statements found in the transcribed interviews were coded. Most of the analysis was done after the coding process was done. However, I took some notes as the coding process went on, as I expected to find similar evidence further in the coding process. Thus, I started looking for patterns before completing the coding and thematizing process.

The interview preparation was highly influenced by the topic of interest and initial research question. The exact formulation of the question was adapted throughout the process, but the area of interest on actor interactions and roles were central from the beginning. Thus, the interview guide was created with these topics of interest in mind. The interview guide is added as Appendix A. Even as some themes was set preliminary through the interview guide, the loose structure of the interviews opened up for the conversation to go into other directions which created new categories not initially defined.

The interviews have gone through two processes of translation, first from oral to written word. Second, interesting statements have been translated from Norwegian to English, which are presented as findings in the empirical chapter. Including these statements is important to highlight the experiences and thoughts. This translation process is done as carefully as possible, to ensure that the true meaning is not lost in translation.

3.5. Ensuring Quality of Research

When conducting a research project, measures should be made to ensure the quality of the research, and entail checking the research design's validity and reliability (Yin 2009:40). Internal validity was secured through interviewing actors involved in different projects, to uncover any rival

explanations for a finding. Additionally, the preliminary research on the case gave me as a researcher a thorough understanding of the background and different views among actors. As for construct validity, when topics were discussed in the interviews, I asked follow-up questions for clarifications to ensure that the statement was understood correctly. This was particularly important, being a student with little experience on interviewing. Even as the study investigates a unique case, considerations for external validity is considered as generalization can be done in for supporting theoretical claims. Further, the case is thoroughly defined, and thus, similar cross-sectoral experiments in early phase of transitions may find similar conclusions as this research. Lastly, reliability is secured as if others were to do the same research, within the limits of regulations and considerations for privacy of informants, they could retrieve the constructed database of documents and transcriptions of the interviews. Also, as this thesis is transparent in regard to what type of actors were interviewed, of the coding process, it should be possible to follow the same steps and retrieve similar output.

3.6. Ethical Considerations

Before starting the data collection, an application was sent to and approved by the Norwegian Centre for Research Data, which guidelines were followed to ensure safe processing of the data. Before conducting the interviews, informed consent was gathered from all informants to ensure they knew their rights and how the collected data would be handled. All personal data gathered was available publicly, and throughout the transcription process, personal names was anonymized.

3.7. Limitations

A limitation concerning the research design and case study is regarding time constraints. The case of electrification of construction sites are constantly evolving as technological solutions improve, new projects are initiated and the market for electrical machinery evolves. Additionally, policy changes may come in the future, changing the direction of how to reach zero emission on

construction sites. Also, other technological solutions may become increasingly prominent, substantially disrupting a potential transition towards electrification. These aspects are examples made to highlight how the study showing how dynamics between actors and what happens at the construction site may not be applicable in a few years.

4. EMPIRICAL FINDINGS AND ANALYSIS

So far, the research area and topic of cross-sectoral sustainability experiments and the role of individual actors have been thoroughly discussed through the introduction and theory chapter. This research area and topic of interest have led to the research question regarding how actor roles and interactions are shaped in cross-sectoral sustainability experiments, which this thesis attempts to answer to provide further insight to the research debate. To answer this question, a single-case study has been conducted, using the empirical case of electrification of construction sites in Norway, aimed at contributing with insight to research on the role of actors and cross-sectoral experiments in sustainability transition. In this chapter, the findings from the analysis will be presented, in addition to connecting them to the theoretical foundation presented in chapter 2. This chapter is divided into sections including findings connected to actor interactions and actor roles, respectively.

4.1. Findings connected to cross-sectoral actor interactions

One of the main objectives of this thesis is investigating how actor interactions are shaped in cross-sector sustainability experiments. The data material provides findings that will help answer this

part of the research question. In this section, the findings related to actor interactions and how the context of system interactions shape these are presented, followed by a summary of key findings.

4.1.1. Cross-sectoral experiments for testing new technologies as sites of interaction

The existing research literature discussing interaction across multiple systems in sustainability transition often use cases of energy transitions as the empirical case for analyzing these dynamics (Köhler et al. 2019; Rosenbloom 2019). These cases often focus on how deep decarbonization need couplings of the energy system providing renewable energy to building, industry, and transport (Köhler et al. 2019; Markard 2018). This view has enhanced the interest in researching multi-system interactions within the context of sustainability transitions. The case of electrification of construction sites may use similar argument for investigating aspects regarding interactions across sectors, as it involves actors from multiple systems. The electrification of construction sites involves the building and construction sector, with all its actors, regulations, and institutions. However, as the transition in question is regarding electrifying a system currently dominated by fossil fuels, the transition will involve changes in how the energy system relates to the building-, and construction sector, which is one of the reasons why this case is appropriate for researching such cross-sectoral dynamics. Additionally, through the preliminary research on the case, it became apparent how the public sector has played an important role in putting electrification of construction on the agenda. Thus, the decision landed on interviewing actors from these three main sectors as they were identified as most involved in the case. What follows is a presentation of the findings related to the theme of system interaction, with the aim to identify some aspects of actor interactions across systems.

The experiments aimed at testing and developing technologies for electrification of construction sites create "sites of interaction" between the building-, and construction sector, energy sector, and public sector. The informants all participate in one or more pilot project or other initiative which aims to test electrical machinery and related technologies at building-, and construction sites. These projects can be conceptualized as sustainability experiments, which are planned initiatives involving multiple actors, aimed at testing radical innovations in sites of experimental learning (Sengers et al. 2019). The experiments that the informants participate in, involve actors from the building-, and construction sector, energy sector and public sector. Thus, the site of *experimental learning* happens at the interface between these sectors.

The experiments where public authorities, firms in the building-, and construction sector and electricity companies come together to test electrical machinery can be conceptualized as a *site of interaction* (Rosenbloom 2019). The rationale behind this conceptualization is that these experiments create a space and purpose for interactions at the interface of these three sectors. This claim is supported by evidence from the data material. A contractor participating in such experiments made this statement:

> *"The project planning was set in motion, and now we saw a new actor that had not been present in the project planning earlier, and that was an electricity company with mobile energy" (Informant C, 5:55).*

This statement shows how the project for testing electrical machinery and mobile energy for providing sufficient electricity for the machines created a *space for interaction* between these actors from the building-, and construction sector, and energy sector. Further, an electricity company discuss how issues regarding the technical aspects of testing the technologies led them to collaborating with machine suppliers and contractors.

> *"We saw how construction sites have some specific, different challenges than a building site, and started collaborating with the contractors, and "machine supplier" that rebuilds these machines to electric, and "rental company"" (Informant F, 5:49).*

This statement highlights that to solve technical difficulties when trying technological solutions for the use of electrical machinery at construction sites, multiple actors from different sectors within the market *realm* form alliances, and interact because of experiments and tests of new, radical innovations. These interactions, however, do not only happen between market actors. The same electricity company state how similar projects are conducted in collaboration with a municipality.

> *"We have an R&D-collaboration with "Municipality", where we contribute with specialists and insight in dimensioning the electricity requirements and energy solutions for building sites" (Informant F, 16:33).*

These examples show how experiments lead to interactions among actors across systems. Below is a figure adapted from Rosenbloom's model of interaction between socio-technical systems (Rosenbloom 2019). It is a visual representation of the three main sectors contributing to the sustainability experiments that constitute the case, and the interaction site at the interface between them.

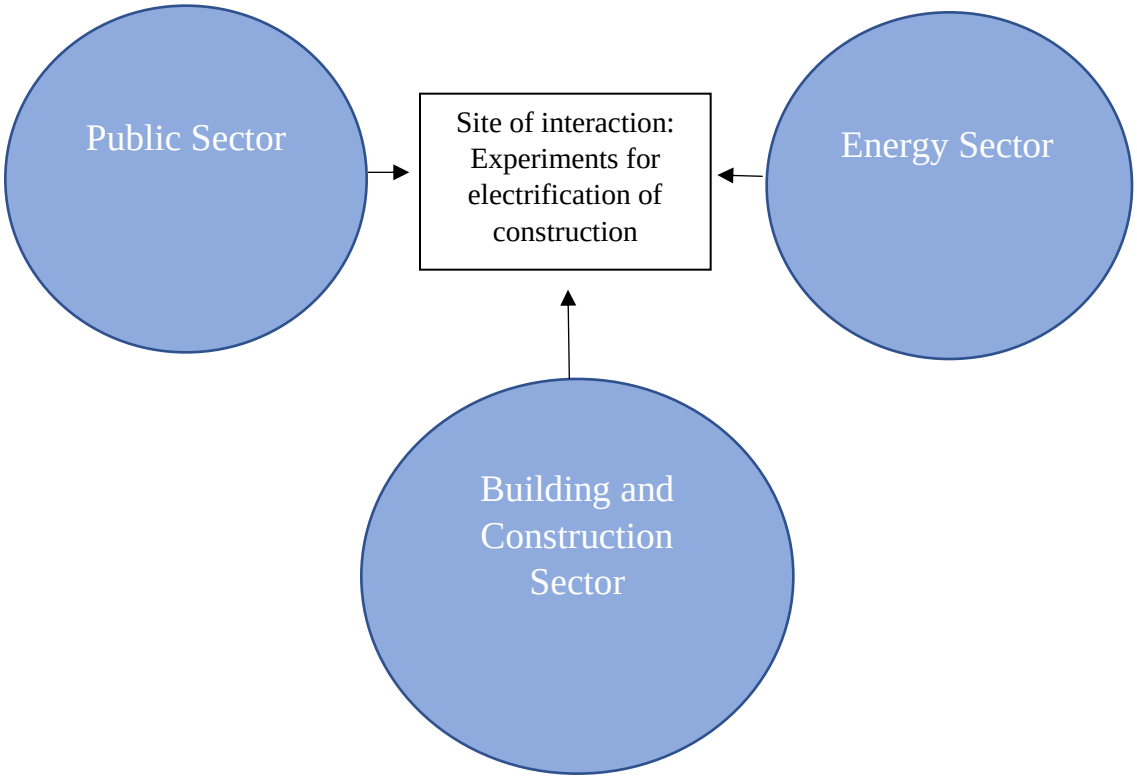

Figure 3: Adapted from Rosenbloom 2019

So far, I have shown how projects how projects where electrical machinery are tested at construction sites contribute to the creation of interaction spaces between project participants across sectors. Even as the tests and trials are conducted at the physical space and domain of the building-, and construction sector, they become intertwined with actors from other systems that become involved in such projects. This leads to **new** linkages between individual actors from these three sectors, in addition to **untraditional** linkages.

The pilot projects where electric machinery was tested connect actors from across sectors. This involves public municipalities as public developers, firms such as machine suppliers, contractors, private developers, and companies providing electricity to construction sites. The informants express that the experiments in which they participate in create new linkages with other actors and creates space and opportunity for them to sit in the same room as new collaborative partners. A

contractor working on a pilot project for electrification express how this project enabled new networks with the following statement:

> *"It opens up new networks …, suddenly there are some actors we have never interacted with in a building project who contributes now, and that is exiting." (Informant C, 49:27).*

The new linkage in this context is with an electricity company providing mobile battery solutions for charging electric machines where there is insufficient power in the electrical distribution grid. The same type of statement was made by an informant from the development department in a municipality, engaged in constellations for testing electrical machines.

> *"We have established good contact with the electricity company, we sort of have a contact person that we contact, and we get quick feedback on what is available (of electricity), so that is something new we have established" (Informant G, 42:10).*

This statement shows how a new link have been made between the public developer and electricity company. In addition to these experiments creating *new* linkages between cross-sectoral actors, some of these linkages are by the actors themselves depicted as *untraditional*.

> *"Yes, it's untraditional because we are sitting in the same room as those who produce the battery, (…) and the contractor, rental company and electricity company. We are trying to find the solutions together, so in that sense it is untraditional" (Informant B, 28:28*).

These findings substantiate the claim that the experiments lead to new and untraditional actor linkages. Seeing that these links are untraditional and happen in interaction spaces that have emerged in the context of experimentation projects, this could entail that these experiments create spaces for interaction between actors who would otherwise not interact, or at least that there is a change in the way they interact.

The concepts of system interaction are concerned with higher level interactions and may consequently be difficult to grasp. However, when different systems meet and interaction spaces are created, this will have implications at a micro-level. The micro-level linkages that emerge from cross-sectoral interactions are thus important parts of this system interaction. Figure 4 includes some of the new or strengthened linkages that have emerged from the experiments as new sites for interaction between these sectors and show how these linkages exceeds the boundaries of systems. The figure is a representation of a few of the linkages that emerged through these experiments. This includes connections between electricity company and machine supplier, and actors from the public sector. The dotted lines represent linkages that existed prior to the experiments, but which have become tighter or changed through these experiments, whereas the full lines represent new linkages.

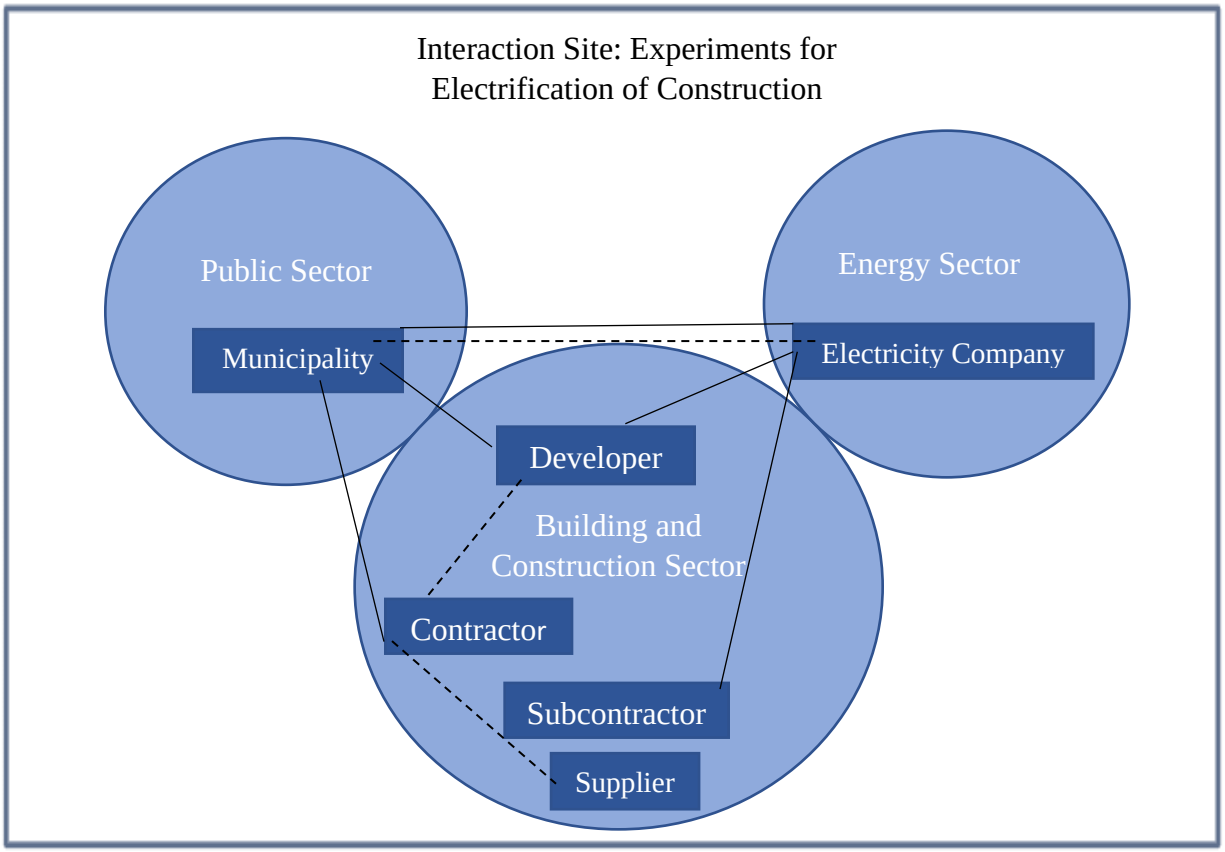

FIGURE 4: MODEL OF NEW AND STRENGTHENED ACTORS LINKAGES, DAPTED FROM ROSENBLOOM 2019

4.1.2. The Electrified versus Traditional Construction Site

The experiences derived from the experiments for testing electrical technological solutions at construction sites have provided insight to what is done differently when electrical machines are used in contrast to when conventional machines are used. Looking into some aspects on how interactions among the cross-sectoral actors differs at construction projects where electrical machines are used may help provide insight to how this new way of executing a construction site may affect actor interactions.

One aspect where electrical construction sites differ from traditional, is the substantial role of electricity. The electrified construction requires more electricity and infrastructure than traditional constructions sites, and at earlier stages of the projects. This also have implications for the combination of physical artefacts at the site.

First, the amount of electricity required for using electrical machinery is substantially higher than at traditional construction sites, which means that there is a need for more electricity to make sure that sufficient electricity reaches the construction site. Additionally, the electrical machines need large amounts of electricity in short periods of time, meaning that the power requirements from the distribution and electricity grid can become an issue.

> *"Construction sites have always requested electricity. What is new is that they request more electricity, and often want it much sooner". (Informant F, 48:51)*

As the electrification of construction site requires higher amounts of electricity, there is a need for increased *infrastructure* and change in what physical components are required at the site. As the electricity is required at an earlier stage than at traditional construction sites, the infrastructure also need to be implemented earlier. A contractor responsible for the project site where electric machines were tested made the following statement:

"Now, you need a single electrical cabinet that you need to get power to toilets, a sink and an office, and that's all you need the first months on the project. But if you are going to have a machine park based on electricity, you need more infrastructure early in the project" (Informant D, 27:02).

The experiment which is referred to in this statement is a project where electrical machines were used, powered by a mobile battery-container that was placed at the site. This new physical component needed to be included early in the planning phase, to find an appropriate spot where it did not interfere with the work.

In addition to requiring different physical components and increased access to electricity at the construction sites, knowledge on how to charge these new machines, and on how much electricity is required at what stages of the building or construction project is necessary. The new competencies and knowledge are highly connected to the increased requirements of electricity and infrastructure. A machine supplier which rebuilds and sell electrical machinery state that one might say that a new form of discipline has emerged.

"But then we arrive with an electrical machine, and we see that it has become sort of its own discipline, electrical infrastructure. The contractor had no prerequisites for knowing anything about this. We didn't either. But we see that we then become an advisory party (...)" (Informant A, 40:56).

This statement substantiates the claim that new competencies are required as the element of electricity become more prominent at the construction site and shows that knowledge on the use of these machines in the industry is lacking.

Further, as presented in the previous section, a public developer discuss how they have established contact with someone from the energy sector to get the required information on the electricity available that they need to use electrical machinery on their construction sites. Thus, one might argue that the increased need for electricity shape actor interactions, as more frequent interactions across systems are required for successful experimentation. This means that the challenge of attaining sufficient electricity to construction sites have implications for actor interactions as this leads to the need for interaction with actors from the energy sector.

The informants were all involved in a type of experimentation for testing technologies for electrical machinery at construction sites. One of the topics discussed revolved around what important factors was required for successful trials, and in general what conditions needed to be present for successful experiments, and second how "zero emission construction sites" could become a reality. These parts of the conversations uncovered some factors the various actors viewed as success factors of the projects, and aspects of how interactions with the other project's participants shaped outcomes of the projects.

4.1.3. Collaborating for Sustainability Gains

Collaborations in the early stages of a project is perceived as important in the experiments, to successfully integrate the element of electricity at construction sites. As depicted in section 4.1.2, electricity needs to be integrated in the construction site earlier and require more infrastructure in construction sites using electrical machines than in traditional sites. This means that interactions between project owners or executioners, that being private or public developers, and utility companies needs to occur in an early stage to provide sufficient electricity in time.

An equipment rental company participating in a cross-sectoral project highlights how collaborations in an early phase of a project where electrical machines are tested provide space for the development of solutions:

> *«I think that is important going forward, that all actors enter at an earlier stage, to find the good solutions together. (…) you might find the solutions together with the client. (…) In this project, you sit down together and try to find solutions, is this possible to do zero emission?" (Informant B, 16:59).*

This statement shows how actors involved in electrification projects view collaborations as important, and how it even may lead to increased sustainability gains, being the "zero emission solutions". Drawing on the organizational literature which defines cross-sectoral experiments and projects as *hybrid arrangements* depicts the main activities of such actor constellations for sustainability as problem-solving, resource allocation and information sharing" (Klitsie et al. 2018; Selsky and Parker 2005). The statement above exposes how the firm approach this project in such a problem-solving manner, as an important part of the motivation for collaborating. Further, these types of collaborations are according to the literature challenge-led, which further provide motivation for taking a problem-solving approach, as the goal is achieving higher sustainability goals. A utility company also implies how there is a higher goal of reaching zero emissions at construction sites:

> *«During the project period, there is a goal to achieve a 100% zero emission building project. But that is something we need to do together with the industry. We can't do it alone" (Informant F, 28:03).*

Similar to the previous statement, this utility company also calls for collaborations in order to achieve the goals of the project. This motivation of sustainability gains may have implications for the interactions between the collaborating partners, as taking a problem-solving approach to collaborating may make them more likely to take upon new roles.

Based on these statements it becomes apparent how interactions with the utility companies in the early phase of the project planning is important in order to integrate the element of electricity at constriction sites. Interactions at early stage of the project are a recurring theme highlighted by many of the involved parties. A contractor state how early interactions with the energy company is crucial, and how it should be the developer's responsibility to have this contact:

> *«It should come from the developer's s power specifications, that this is thought of in early phase, that they have had a dialogue with the energy provider" (Informant C, 20:25).*

Further, a public developer wanting to use electrical machines at one of their projects points to the issue that might emerge if the component of electricity were not integrated in the early phase of project planning:

> *«We have also been in dialogue with industry associations, conveying the need to turn quite quick, because we are announcing the project, and then the contractor must act fast and give a price. And if that's when they start looking for available machines, then they're already too late" (Informant G, 14:04)*

These statements point to aspects on the importance of interactions in early phases of the project, to ensure successful projects, and how much of this is connected to providing sufficient electricity to the sites. In addition to how early interactions may have implications for the success of the project, a supplier of equipment for construction sites involved in such projects even argue that collaboration in the early phase of a project helps find better solutions leading to better sustainability outcomes:

> *«Having good teamwork in the early phase and finding the solutions early. We often enter when the solutions are already set, and the price of a building is set. Then you deliver a solution based on that. However, being involved in the early phase, that's when you find*

the best solutions together, that have as little impact on the environment as possible" (Informant B, 37:35).

Further, it is uncovered through analyzing the data material that the goals of the cross-sectoral experiments are creating and diffusing knowledge on the use of zero emission technologies at construction sites, and to get experiences transferrable to other projects.

"The goal is to test and get practical experience with necessary electric equipment and necessary infrastructure. Rather than achieving 100% zero emission construction site. But during the project period, there is a goal to also complete a 100% zero emission building project." (Informant F, 28:03)

The goals of a project may have implications for interactions between actors, as

Another important aspect regarding actor interactions in the pilot experimentations is problem-solving. The iterative and problem-solving approach were important for successful interactions between the project participants and leading to better outcomes from the projects. The reason for the positive outcome when working iterative is that it provides quick feedback on what works, and what does not work, meaning that improvements leading to project success may come quicker. A contractor working on such a pilot experiment of testing electrical machinery on their construction site depicts it like this:

Example: *«We have obtained much practical experience and collaborating like that with the user does so there are spaces to develop products and try and fail, and testing these out without having a 100% perfect product. But we do it in a collaborative constellation and receive quick feedback from them. And the purpose is to do iterations on these products" (Informant F, 5:49).*

Having an iterative process on testing these products thus create space for doing iterations along

the way. When discussing the pilot projects or other types of initiatives testing electrical machinery, they point to what they perceive as the main goals of these projects.

4.1.4. Summary of Findings

- The experiments aimed at testing and developing technologies for electrification of construction sites create “sites of interaction” between the building-, and construction sector, energy sector, and public sector

- The sustainability experiments lead to **new** and **untraditional** cross-sector linkages due to contact through sites of interaction

- The electrified construction site requires more electricity and infrastructure and at earlier stages of building-, and construction sites, and requires new combinations of physical artefacts compared to traditional construction sites
- The electrified construction site requires new competencies and knowledge

- Close interactions in the early stages of the projects are perceived as crucial for the success of the use of electrical machinery at construction sites.

- The goals of the cross-sectoral experiments are creating and diffusing knowledge on the use of zero emission technologies at construction sites, and to get experiences transferrable to other projects.

4.2. Findings Connected to Actor Roles

In the previous section, the findings related to the part of actor interactions in cross-sector collaborative experiments were presented, including some aspects of system interactions providing the context of cross-sectoral actor interactions. This section present findings related to the second part of the research question, concerned with actor roles and how they are shaped in these experiments. Among other, all the informants were asked the same questions about the role of their organization or entity in the experiments, resulting in the discovery of patterns concerning their role as participants in experiments testing electrical machinery and related technologies at construction sites.

4.2.1. New and Untraditional Actor Roles

One of the patterns discovered were that among the informants, most had new and untraditional roles in these experiments, compared to their normal operations. This relates to the emergence of new functions as depicted in section 4.1.2., concerned with how in construction sites using electrical machinery requires new things compared to the traditional site. This includes the need for sufficient electricity at the construction site, and increased infrastructure at earlier phases of a construction project. To ensure the physical artefacts, infrastructure and competencies required for successful use of electrical machinery, new actor roles emerge to fill these functions. These new functions that needs to be filled lead to actors taking upon untraditional roles. This related to existing literature on actor roles from transition studies, suggesting that actors take upon different roles throughout the transition (Fischer and Newig 2016). As the transition moves from one phase to another, new tasks emerge, explaining the need for these new roles.

A supplier of electrical machines that rebuild and sell to the market depicts how they take a more active role in the use of machines than when they sell machines that run on diesel. The reason for this change in role is that electrical machines are new, and the customer do not have sufficient competencies of how to use, charge and maintain the machines.

"There are no clients that call us to ask how to fill the tank with diesel, or where they can obtain diesel. But then vi arrive with an electric machine, and then we see that it has become its own discipline, electric infrastructure. (…) The contractor doesn't have the prerequisites to know anything about this. We didn't either, but we see that we become an advisory party between the contractor, developer, and provider of electricity." (Informant A, 40:56).

This statement points to how the machine supplier gained a new role in construction project to secure successful use of their machines, as there was no other designated actor to take this advisory role.

Where the machine supplier takes a new advisory role in the use of machines, someone need to be responsible for obtaining sufficient electricity to the construction sites. In two of the pilot projects that were discussed in the interviews, the project owner being a public developer from a Norwegian municipality took the responsibility of facilitating for electricity and infrastructure to the construction site. Normally, the contractor is responsible for what happens at the construction site, but as this required something new and underdeveloped, these public developers took this untraditional role. One of these public developers presents it in this manner:

«Normally, we would never interfere with how the contractor attains fuel for their machines. This is just to make it (electrical machines) more attractive and help the contractors" (Informant G, 38:43).

Actors from the energy sector participating in experimentation projects for electrification also do things differently than they normally would in building and construction projects.

«Well, we have been involved a lot in building projects (…), we are used to being present

at building sites. But delivering infrastructure for charging is new at building sites is new" (Informant F, 23:25).

These findings substantiate the claim that experiments where testing electrical machinery are used, actors take upon new roles. From the statement of this utility company, it becomes apparent how linkages with the building and construction sector have become tighter as a consequence of these experiments, which is shown in figure 4, displaying how some of the new linkages are new, whereas other are strengthened. Further, this new, more active role at construction sites is a consequence of the increased need for electricity at the construction site.

Further, the informants expressed that they took upon these new roles because of the new functions and tasks that emerged in experiments where electrical machinery where utilized, compared to traditional machinery. The new and untraditional roles that new roles emerge largely due to the new functions that emerge in the experiments, as discussed in section 4.1.2. on the electrified versus traditional construction site. These new functions include ensuring sufficient electricity to the construction site and providing the necessary competencies and knowledge on the electricity aspect and use of electrical machines. Through examining the statements of the informants, one might suggest that they take upon new and untraditional roles, as presented in the previous section, due to these new functions.

4.2.2. Allocation of Roles

Actors have taken upon new and untraditional roles in the execution of projects testing electrical machinery and related technologies, as discussed in section 4.2.1. Further, there poses some uncertainty among the involved parties on how these new roles are allocated in similar projects in the future.

A public actor engaged in such experiments state how they during the project took responsibility for ensuring sufficient electricity to the construction site, which included contact with the local utility company. In hindsight they have stated that they don't want to have this role in future projects as a developer. However, there pose uncertainties for how this plays out in the future. They state:

"However, this might change, and suddenly, the developer has this responsibility eventually, in one way or another" (Informant H, 39:56).

This example show how uncertainty about the future of construction sites and what solutions are best creates uncertainty of who are internalizing the new tasks, or if completely new actors take these roles. Transition scholars discussing actors roles in transitions propose how the role of actors may change when transitions move from one phase to another (Bai et al. 2010; Fischer and Newig 2016). In this view the role actors take in one phase of the transition, such as in the phase of experimentation and market creation as this case, is not necessarily the role they will have at a later point.

In addition to these uncertainties about future roles, some of the actors which did new things in the experiments, stated in hindsight of the projects that they would not take similar roles in future projects. This means that some of the new roles the actors take upon are expected to be *temporary.* A municipal entity working on facilitating for the use of electrical machinery at construction sites stated this concerning their role in present project being in contact with the utility company:

> *"No, it's just now in a transition phase that we see ourselves taking that role. After some time, there will be contracts on deliveries, that there is a designated supplier of electricity. (…) That they deliver complete utility deliveries. Then, the contractor can contact them directly. We will not take those type of roles in the future." (Informant G, 39:50).*

According to the informant from the municipality, they expect that as the market and technological development comes further, other actors will fill the functions they have taken responsibility for in these pilot experiment. They take this role in a transition period and expect other actors to take the role they filled temporarily. The same type of statement is made by another municipality working with similar projects:

> *"Yes, it should not be our …, because we don't know what the contractor wants and how they want to solve it. If they have their own electricity-battery-container, and how found their own ways, then our preparations will be for nothing" (Informant H, 18:46)*

Both these statements show that there are expectations that the market will evolve to the point where the active facilitator role the municipalities take in these experiments will be redundant. Thus, the motivations for this untraditional role of municipalities are due to help drive market creation and development of technological solutions before the market can sustain itself. This is in line with existing transitions literature on actor roles in transitions, suggesting that public actors may act as an enabler for experimentation for sustainability, thus exceeding the traditional role of public actors (Fischer and Newig 2016:7).

In contrast to the expectation of temporary roles made by the public actors, the utility company expect their new role at construction site planning and execution to be permanent, and even increase as the market for electrical machinery increase:

> *"There is a market that will be electrified and needs infrastructure, and here we have a natural role of offering this to the market" (Informant F, 28:08)*

When discussing what is the most important driver for electrification of construction sites, public authorities are highlighted for various reasons. First, many points to actions of public actors as the main reason that experiments for electrification of construction sites are happening in Norway. An actor from the energy sector depicts it like this:

> *"It would likely arrive after a while when the battery technology became very affordable and competitive, so an electrical motor was used instead of fossil. But that it's happening now, that is 100% driven by regulation and demands made by the public" (Informant F, 26:07).*

Additionally, a machine supplier implies that when climate is included in the criteria when deciding on who gets the job, is gives incentives for investing in electrical machines.

> *«When we the public actors weighing in climate criteria in their tender processes, those who dare to invest see that it actually pays off" (Informant A, 17:55).*

These examples show how public authorities contribute directly to market creation, thus taking an active role in transitions. In addition to shaping the market through including climate in the tender process, they take an active role in experiments for testing electrical machinery and take upon tasks not common for public developers or project owners as already discussed.

4.2.3. Summary of Findings

- Actors participating in pilot experiments take upon untraditional roles to fill the emerged functions when testing new technologies.

- Actor roles are evolving over the course of the transition, meaning that the new actor roles may differ when transitions move to another phase.

- There pose uncertainties among the actors involved in sustainability experiments about the future allocation of new roles and tasks that emerged at “electrified” construction sites.

- The public actor expects the functions they filled in the construction site using electrical machinery to be temporary

5 DISCUSSION

This thesis explores the micro level of multi-system interaction/cross-sectoral linkages. Within the existing transitions literature. This thesis is thus located at the intersection between the literature on multi-system interaction and looking into the actor-level dynamics of system interactions. Thus, my contribution to the transitions research is investigating the actor-level dynamics of cross-sectoral interactions.

5.1. System Interaction

The literature on cross-sector dynamics provides relatively new insights to the interactions between multiple systems in sustainability transitions. The scholars concerned with multi-system dynamics argue that sustainability transitions usually involve different sectors, which leads to new cross-sector linkages and interaction sites (Markard 2018; Rosenbloom 2019, 2020).

The approach of this thesis includes investigating the actor-level aspect of multi-system interactions, thus contributing to the research on multi-system interactions by combining these levels of analysis. The units of analysis in the case of electrification of construction sites have been some of the actors participating in experiments for sustainability, where the aim is testing the novel technologies of electrical machinery. What have become apparent through this study is how even as these experiments are initiated by one specific party, both the planning and execution of the projects are being done in cross-sectoral constellations of actors. Thus, these experiments may be depicted as "*sites of interaction*", creating both new and untraditional linkages between actors from across social realms (Rosenbloom 2019). The existing literature on interaction focus on whether symbiotic or competitive patterns are developed through the interactions, an aspect not addressed in thesis (Rosenbloom 2019:21). However, this thesis expands on the understanding of interaction sites through proposing that sustainability experiments as sites of interactions lead to new and

untraditional linkages between actors participating in such project that would not have connected elsewhere. One example is how the electricity company are sitting in the same room as machine suppliers, trying to find the best technological solutions for the construction sites. This actor interaction would not have happened were it not for the sustainability experiment. In addition to creating new linkages between actors, others have been strengthened, meaning that due to these experiments, actors that interaction on one level became increasingly intertwined through these projects. A representation of new and strengthened linkages are presented in figure 3, chapter 4.1.1. The notion that sites of interactions lead to new linkages aligns with Rosenbloom's research. The contribution of this thesis to this view is combining the concept of sustainability experiments with cross-sectoral dynamics, as a way of investigating actor level dynamics in these types of experiments.

Rosenbloom have characterized multi-system interactions as diverse, layered and evolving (Rosenbloom 2020). These interactions being evolving mean that they change over time, a claim that is substantiated by the findings of this study. (Rosenbloom 2020:337). Analyzing the data material uncovered how actor networks and linkages have evolved from prior to the experiments and during the projects. In the empirical section on how the "electrified construction site" differs from the "traditional construction site", specific evidence regarding the change of actor interactions is found. Among other, it is uncovered how the relationships between actors from the energy sector and building-, and construction sector have become tighter as they form networks to solve any issues that might emerge when using electrical machinery at construction sites and requiring substantially larger amounts of electricity and at an earlier phase than at traditional sites. The latter result in the need to be in contact with the electricity companies more frequent, and earlier in a construction project than in traditional project. In this case, these systems have become increasingly intertwined through interaction at the site of interaction, findings which substantiate the claim of previous research, suggesting that system interaction evolve over time (Rosenbloom 2020:337). Rosenbloom describe system interactions as evolving over time (Rosenbloom 2020). My addition to this insight is through the findings of this thesis suggesting that as system interactions evolve, actor linkages may become tighter.

Jochen Markard discuss how a sector during a transition interact with the wider context and adjacent sectors, and thus affect and are affected by them (Markard 2018:630). For the case of electrification of construction sites, the domain of the transition is the building-, and construction sector, and two of the identified adjacent sectors are energy and the public sector responsible for policymaking. From the findings presented in the empirical chapter, dynamics where the focal sector is affected by adjacent sectors are uncovered. The public sector seems to have particular effect on the building and construction sector in terms of transitioning. The informants all point to political ambitions, carbon emission targets, expectations of regulations and public procurement as important driving forces of the transition in within the construction industry. Second, these political decisions and signals shape both the direction and speed of the transition. For one, when municipalities decide to use electric machines in their own development projects, this increases the demand for these types of machines, and help boost the technological development, and market creation. Thus, adjacent sectors such as the public may have large impacts on surrounding sectors, and the view of acknowledging and importance of doing transitions research on the actions of adjacent sectors, and to a large extent the political environment is substantiated by this research project. Further, Markard argue that adjacent sectors are "hardly affected" during the first phase of transitions in a focal sector (Markard 2018:630). When the transition moves to the second stage characterized by enhanced diffusion, the effect on other systems is likely larger than in the first phase, as Markard suggest. Based on the evidence in this study, however, I would argue that looking into cross-sector interaction may present useful insight to transition processes which involves multiple sectors, even in early phases of transitions. For one, in the case of electrification of construction, multiple systems are interconnected at a very early stage. I would argue that the transition even depends on these cross-sectoral interactions. An implication for further research would thus be to include research on cross-sectoral dynamics in early stages of transitions, not limiting the research to how technologies emerge in niches, and new entrants.

5.2. Actor Roles in Sustainability Experiments

The second research question seeks to investigate how actor roles are shaped in cross-sectoral sustainability experiments. Researching actor roles may contribute to research on cross-sectoral dynamics as the actors perspective have gotten less attention in transitions literature, even as it is beginning to gain increased interest within the field (Farla et al. 2012a; Fischer and Newig 2016).

One of the key findings from the case of electrification of construction sites is how actors take upon untraditional roles in construction projects using electrical machinery at construction sites, compared to in traditional projects. The experiments researched in this project were all multi-actor initiatives, either consisting of constellations of actors, partnerships, or normal business-relationships with both traditional and untraditional business associates. All the informants mentioned in one way or another that their interactions with others in these projects were highly oriented towards problem-solving. The findings substantiate the claim that actors take upon untraditional roles in the experiments, as a way of ensuring success for the experiments. The findings suggest that public actors specifically take untraditional roles, as ensuring sufficient electricity to construction sites. In addition, this thesis finds evidence that public actors take a leading role in facilitating for sustainability experiment. These findings corroborates with claims from existing transitions literature, suggesting that public actors take increasingly more active roles in sustainability transitions through enabling experimentation (Fischer and Newig 2016; Foxon et al. 2008; Quitzau et al. 2012).

The transitions literature on actors suggests that roles are evolving and may change over time, as transitions unfolds (Fischer and Newig 2016). This claim is substantiated by the findings in this thesis, such as how public actors took responsibility for ensuring sufficient electricity to construction sites in the early stages of transition and market formation, but later stated that they would not take such roles in future projects.

As a way of expanding on the notion that actor roles are evolving, this thesis suggests substantiated by the evidence, that there poses great uncertainty around the future allocation of roles among potential actors. The new tasks emerged through the experimentations initially led to actors taking untraditional roles due to the problem-solving nature of sustainability experiments and wanting successful execution and to get started on creating knowledge. Some of the market actors have articulated desire to integrate these new roles and tasks as a part of their business strategy, whereas the public actors state that the things in which they did different in experiments where electrical machinery were used compared to in traditional construction projects, were temporary. Thus, who should take these roles in similar projects in the future is uncertain. This implies that actors doing new things in cross-sector sustainability activities not necessarily have permanent implications on actor roles. This aligns with studies on actors in transitions, which address how allocation of roles may differ in different stages of transitions (Fischer and Newig 2016; Grin et al. 2010; Kemp et al. 2007). Further, they argue that actors should be studied in different phases of transitions (Fischer and Newig 2016; Grin et al. 2010; Kemp et al. 2007). For further research, this could imply looking into how actors participating in such experiments and do new things rethinks their role and identity throughout the transition process. The findings of this thesis uncovered how in the point in transition of testing new technologies and market creation, there poses great uncertainty about the future of roles. Even as the public actor articulated the expectation of their new role to be temporary, the also acknowledge that due to uncertainties regarding future allocation of roles in electrified construction sites, they could not completely reject the possibility of permanently change their role.

So far, discussion on findings connected actor roles and interactions in cross-sectoral experiments have been discussed separately. Nevertheless, aspects on one may have implications for the other and be tightly linked. When discussing actor interactions in the empirical chapter (4.1.3.), it was uncovered how actors participating in cross-sectoral sustainability experiments take a problem-solving approach to the projects due to the motivation of achieving sustainability gains. This finding was in line with research from organization studies on challenge-led, project-based initiatives (Klitsie et al. 2018; Selsky and Parker 2005). Further, when analyzing data material related to actor roles, it was exposed how actors took untraditional roles to secure successful testing

of the electrical machinery in these experiments, which points to a problem-solving way of thinking. Thus, one might argue that the problem-solving approach of cross-sectoral experiments lead to actors take upon untraditional roles. A contribution to the research on actors in cross-sectoral interactions is combining concepts on challenge-led collaborations from organizational with the transitions literature, suggesting that the goal of achieving sustainability goals lead to actors take upon untraditional roles in cross-sector experiments to secure successful experimentation (Fischer and Newig 2016; Klitsie et al. 2018; Selsky and Parker 2005).

6. CONCLUSION

As climate changes have become more pressing, actors from the private and public sectors increasingly engage in sustainability activities aimed at mitigating carbon emissions throughout the society. Research on sustainability transitions have thus gained increasing attention, and have emerged as its own research field (Köhler et al. 2019). Transition pathways towards sustainability often involve multiple sectors, such as energy transitions involving a shift towards use of renewable energy sources as a way of reducing carbon emissions from fossil fuels. Thus, research on cross-sectoral dynamics may contribute to increased understanding of sustainability transitions (Andersen et al. 2020; Rosenbloom 2019). This thesis has, through conducting a case study research on electrification of construction sites in Norway, attempted to contribute with insight to research on actor roles and interaction, in addition to point to aspects regarding cross-sectoral dynamics. This thesis contributes to the research by exploring actor-level dynamics within a multi-system perspective.

Throughout this thesis, the research question of *how actor roles and actor interactions are shaped in cross-sectoral sustainability experiments* have been investigated. The contribution to the research includes the emerging claim that sustainability experiments constitute sites of interactions

which leads to **new** and **untraditional** linkages between actors from multiple sectors. Further, this thesis expands on the existing research on cross-sectoral interactions through investigating actor roles within this context. The key findings include how the sites of interaction lead to actors taking untraditional *roles* in sustainability experiments. The evidence from this thesis suggests that an explanation for these new roles is due to the new tasks that emerge in experimentation with new technological solutions, in addition to the problem-solving nature of the constellations of actors that participate in the experiments.

Further, transition scholars call for research on cross-sectoral interactions in later stages of transitions and argue that adjacent sectors hardly is affected when a transition is in its early stages (Markard 2018). Through this study, it has become apparent that cross-sectoral dynamics have implications for actors and interactions on a micro-level. Thus, a suggestion for further research on the topic revolves around investigating multi-sector dynamics also in early phases of transitions, as it may lead to useful insight to sustainability transitions.

The study conducted in this thesis contribute to research by pointing to aspects on actor roles and interactions and cross-sectoral dynamics in an early phase of transitions. One strength of the study lies in a thorough background research on the empirical case and interviews with how key informants involved in multiple electrification projects. Second, at the point of this research project, a very interesting point in time of the electrification transition was observed, as allocation of actor roles are in flux, and the integration of the electricity system in the building-, and construction sector is relatively new. A weakness, however, is how the study of the empirical case has looked at the case of electrification of construction over a short period of time. For further research, the case over a longer period could give fruitful insight to the research on how the role of actors and change over the course of transitions, in addition to allocation of roles and aspects on cross-sectoral interaction.

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Appendix A

Interview guide. Translated from Norwegian (original) to English.

INTERVIEW GUIDE

Formally:

- Repetition of data management and the rights of the informant
- Information about the project

Beginning:

- Can you introduce yourself, and your role in (firm/organization)?
- Can you briefly introduce how you became involved in project(s) aimed at promoting zero emission construction sites?

Involvement in pilot project/initiative:

- How did it begin?
- What is the role of (firm/organization) in the project(s)?
- What have you learned?
- On interaction with collaborative partners: What have been the benefits/challenges? Have there been any new/untraditional collaborators?
- Have the roles of the different participants changed throughout the project?

- What is done differently when using electrical machinery at construction sites versus at traditional sites (fossil fueled machines)?

Policy:

- What has been the role of policy and public initiatives in the development of zero emission construction sites?
- Have you experienced having any influence on policymaking?

Drivers and barriers:

- Where do you see the future of zero emission construction sites going?
- What conditions must be present for it to become a reality?

Ending:

- Is there anything else we should talk about that we have not addressed so far?

Appendix B

Codebook – Electrification of Construction

Nodes\\Thematic coding

Name	Description	References
Actor roles	General data connected to actor roles	13
Change	Changing actor roles	7
Expectations	Expectations for future roles	4
Firms	Firm-specific roles	24
Public authorities	Public actor-specific roles	9
Collective action and interactions	Data connected to collaboration in general	15
Actor interactions	Interactions between project participants	14
Cross-sector interaction	Data specifically related to interactions across sectors	13
Experimentation	Data regarding the experiments	13
Change	How things are done at construction sites for these experiments differ from traditional projects	17
Experiences	Experiences and what the informants have learned	11

Name	Description	References
Goals	Goal of experiment as articulated by the participant	6
Iterative Process	Learning and making iterations throughout the experimentation process	5
Knowledge diffusion	Sharing knowledge after experimentation	2
Infrastructure	Aspects on the need for infrastructure	11
Market and price	Market for electrical machinery	22
Narrative - Timeline	Time, dates, and thoughts regarding the future of zero emission construction sites	12
Policy	Policy and how they shape electrification of construction	15
System Interaction	Data on how larger systems interact	8
Electricity	Specific system interactions with the electricity system	14
Technological development	Aspects regarding where the technological development is at	5
Waiting game	Data suggesting that actors wait for action from others to take the first step in electrifying	6