Finland in energy transition

The interplay between actors and institutions and the application of climate abatement technologies

Laura Kainiemi
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**Abstract**
A significant gap remains between the goals set in the Paris Agreement and the emission reduction measures that have been implemented since. One of the reasons for this policy gap lies in technological trajectories and institutions which have formed to support existing technologies. This dissertation explores the interactions between actors and institutions in order to determine the influences on the deployment of climate abatement technologies and the direction of the energy transition.

Institutional environments, which vary from one country to another, are comprised of formal rules and regulations, as well as informal practices, beliefs, and expectations. Countries with centralized energy production tend to have relatively stable institutional environments, which are more resistant to change. This dissertation is focused on Finland, which has a relatively centralized energy sector with well-established institutions. A technological innovation systems (TIS) analysis is performed to determine the level of institutional support for sustainable technologies and to evaluate the level of destabilization policies.

Institutions can be altered through collective, often conflicting actions, performed by various actors in the energy sector. Actors can influence their institutional environment through strategic institutional work, or through their framings of energy issues. These influences could be reflected in the direction of the energy transition and the adoption of climate mitigation technologies. Actors’ influences are mapped using documentary material and three interview sets, where actors include representatives from industry, research, and academia; policymakers, ENGOs, and citizen activists. Interviewed actors include energy policy actors and CCGS and CO₂ mineralization experts.

The results demonstrate that the level of destabilization policies in Finland is low, and existing institutions present obstacles for climate change abatement technologies, such as CO₂ mineralization and sustainable energy. Dominant framings have defined the observed technologies as having a marginal role in the energy sector, and this has also become cemented into formal institutions, creating obstacles for these technologies. Actors’ choices of the activities they engage in are limited by surrounding institutions because actions that do not fit into the institutional environment are more likely to be rejected by others. The collective result of actors’ conflicting strategic actions is affected by their positions in the sector, which means that traditional actors, who have strong, institutionally defined positions in the energy system, have more influence over institutional development.

The results of this dissertation highlight the complex and interlinked nature of the interactions between actors and institutions and do not support a significant transition. They indicate that, while the energy sector is developing towards carbon neutrality, this development is taking place...

**Keywords** Energy transition, institutions, actors, climate abatement, technology deployment

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Tiivistelmä
Tällä hetkellä käytössä olevat päästöjen vähennyskeinot ovat riittämättömiä Pariisin ilmastosopimuksen tavoitteiden saavuttamiseksi. Toimenpiteiden riittämättömyyteen vaikuttavat tekno logoiden kehityspolut ja niiden ympä rille kehittyneet instituutiot. Tässä väitöskirjassa tarkastellaan instituutiojen ja toimijoiden välisen vuorovaikutuksen energiamurroksen sekä ilmastonmuutosta torjuvien tekno logoiden käyttöönottoon kohdistuvaa vaikutusta Suomessa.


Tulokset korostavat toimijoiden ja instituutioiden välillä vallitsevan vuorovaikutuksen monimuutkaisuutta. Ne osoittavat miten stabiilissä institutionaalisessa ympäristössä energiamurros pyrki noudattamaan olemassa olevia kehityspolkuja, keskittynyt hillineutraalisuuteen radikaalimman murroksen sijaan.

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Laura Elina Kainiemi
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# List of Abbreviations and Symbols

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>CO2</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>CCUS</td>
<td>Carbon Capture, Utilization, and Storage</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>TIS</td>
<td>Technological Innovation System</td>
</tr>
<tr>
<td>ReDE</td>
<td>Renewable decentralized energy</td>
</tr>
<tr>
<td>TEM</td>
<td>Työ- ja elinkeinoministeriö - The Ministry of Economic Affairs and Employment of Finland</td>
</tr>
<tr>
<td>CCGS</td>
<td>Carbon Capture and Geological Storage</td>
</tr>
<tr>
<td>CCS</td>
<td>Carbon Capture and Storage</td>
</tr>
<tr>
<td>EU ETS</td>
<td>European Union Emission Trading Programme</td>
</tr>
<tr>
<td>BECCS</td>
<td>Bioenergy with carbon capture and storage</td>
</tr>
<tr>
<td>bio-CLC</td>
<td>Chemical-looping combustion of biomass</td>
</tr>
<tr>
<td>PCC</td>
<td>Precipitated Calcium Carbonate</td>
</tr>
<tr>
<td>ENGO</td>
<td>Environmental non-governmental organization</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-governmental organization</td>
</tr>
<tr>
<td>VATT</td>
<td>VATT Institute for Economic Research</td>
</tr>
<tr>
<td>FCEA</td>
<td>Finnish Clean Energy Association</td>
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List of Publications

This doctoral dissertation consists of a summary and of the following publications which are referred to in the text by their numerals.


Author’s Contribution

**Publication 1:** Renovation realities: Actors, institutional work and the struggle to transform Finnish energy policy.

The article was written by Laura Kainiemi and Kamilla Karhunmaa, with contributions from Sanni Eloneva. Laura Kainiemi coordinated the writing process and collected the supplementary material. The interviews were conducted by Kamilla Karhunmaa and Sanni Eloneva. Planning the interviews, coding and analysing the results, and drafting the article were done in co-operation with all three authors, in an iterative process. The author contributed to all sections in the manuscript.

**Publication 2:** Transition towards a decentralised energy system: Analysing prospects for innovation facilitation and regime destabilisation in Finland.

Co-authored with Sanni Eloneva and Jarkko Levänen. The author had the main responsibility for data collection, analysis, and paper writing. Sanni Eloneva participated in writing and analysis, while Jarkko Levänen helped formulate the research questions and edit writing.

**Publication 3:** Opportunities and obstacles for CO2 mineralization: CO2 mineralization-specific frames in the interviews of Finnish CCS experts.

Co-authored with Sanni Eloneva, Arho Toikka, Jarkko Levänen, and Mika Järvinen. The author had the main responsibility for analysis and paper writing. The interviews were planned and conducted together with Arho Toikka, and the results were coded and analysed with Sanni Eloneva. Sanni Eloneva and Jarkko Levänen participated in writing and editing, while Mika Järvinen provided helpful comments.
1. Introduction

Climate change abatement has become an increasingly pressing issue in recent years, following research findings which indicate how the negative impacts are happening sooner than expected (IPCC, 2018). Increasingly ambitious emission reduction targets have been introduced in order to mitigate these impacts, but studies show that current measures are insufficient to reach them. The Paris Agreement amended the previous aim of limiting global warming to 2 degrees Celsius to the new aim of 1.5 degrees Celsius in order to reduce the impacts of climate change and lessen the risks of severe effects (UNFCCC, 2018). In its new special report, the IPCC (2018) predicts that, continuing on current emission levels, there could remain only a few decades to avoid exceeding the target. In order to avoid exceeding a 1.5-degree increase, or to allow for a slight overshoot, CO2 emissions would have to be reduced by 45% from 2010 levels by 2030, and reach net zero by 2050. Current climate change abatement measures, however, are insufficient to keep the level of global warming beneath even 2 degrees Celsius (European Commission, 2019b). Limiting global warming to 1.5 or 2 degrees would require significant emissions reductions in all sectors, using a wide range of mitigation technologies (Figure 1); in the energy sector, these would include renewables, energy efficiency, nuclear energy, CCUS (Carbon Capture, Utilization and Storage), and fuel-switching (IPCC, 2018; IEA, 2019).
The magnitude of these reductions would require transitions in the fields of energy, land use, industry and infrastructure on an unprecedented scale (IPCC, 2018). Transitions signify fundamental and multi-dimensional transformations towards more sustainable consumption and production patterns (Smith et al., 2005). These transformations can be considered as transitions when they are directed by specific goals, such as maintaining global average warming under 1.5 degrees (Berkhout, 2006). Transitions require profound changes in socio-technical systems. These systems encompass sectors, such as energy, that provide a service to society (Markard et al., 2012), and they consist of technologies and knowledge, actors, actor networks, and institutions, such as norms, regulations, and standards (Geels, 2004; Markard, 2011; Weber, 2003). In other words, systems include different structures within a sector, including technological, economic, institutional, political organization, and cultural aspects (Markard et al., 2012). Issues like climate change tend to present time pressures, and measures to solve them need to be implemented quickly (Farla et al., 2012). On the other hand, transitions can take a long time to unfold due to the fundamental changes they entail, even exceeding 50 years (Markard et al., 2012). In order to limit the rise of global average temperatures, and thereby to meet the new targets, significant changes will need to take place in how energy is produced, stored, distributed, and consumed.
Change in socio-technical systems generally takes place incrementally, due to the interlinkages between existing technologies and their institutional environment (Markard and Truffer 2006). Socio-technical systems can be resistant to change when practices, governance structures, and manufacturing processes have become embedded as rules which have been widely adopted by various actors (Geels, 2002). The institutions that govern activities in socio-technical systems create stability by directing innovation activity towards incremental improvements (Geels, 2002), and these institutions can be formal, such as laws, regulations, and other guidelines, or informal norms and practices that have become widely accepted (Scott, 2013). Innovations will not be able to become part of a system if they are not aligned with the institutions and values of the regime actors (Kemp et al., 2001). Incremental innovations, however, are insufficient in the face of current sustainability challenges (Markard et al., 2012). This innovation bias can lead to technology lock-ins in which the socio-technical system is locked into a technological trajectory due to a high level of interconnectness between institutions, business models, value chains, and users’ lifestyles (Rip and Kemp, 1998). In short, technology lock-ins can slow down transitions (Unruh, 2000).

To create spaces for innovation that do not follow technological trajectories, research suggests that destabilizing existing system elements is necessary (Kivimaa and Kern, 2016). Destabilization is the process of displacing parts of the regime to create spaces for innovations and actors to enter the system. While some studies define destabilization as the replacement of actors (Normann, 2019), others utilize a wider definition of replacing system elements (institutions, actors, technologies) (Kungl and Geels, 2018; Turnheim and Geels, 2012; Johnstone and Stirling, 2015). Resilient systems can resist and adapt to policy changes by creating complementary innovations based on existing technologies, for example, by employing emission removal technologies as a response to reduction regulations (Hansson and Bryngelsson, 2009).

Transition studies aim to analyse systemic changes, such as the transition of an energy system, including the technology choices, institutions, and actors this transformation involves (Markard et al., 2012). The focus of energy transition studies has been on norms and institutions, and the influence of actors and agency has not been addressed sufficiently (Geels, 2014), despite the fact that actors can play significant roles in transitions (Haukkala, 2018; Brown et al., 2013), as they can either support or displace system elements (Kuokkanen et al., 2018). Although recent studies have started to pay increasing attention to agency and actors, they have been criticized for focusing only on the efforts of challenging actors, while overlooking actors who seek to maintain existing institutions (Hess, 2013). Although powerful actors have more resources to influence policy (Avelino and Rotmans, 2009) and can contribute to upholding trajectories, the conflation of system maintaining regime actors and destabilizing/challenging actors can be seen as a coarse generalization of a complex reality — a reality in which multiple actors seek to influence their institutional surroundings in order to improve their position in the energy system (Sovacool et
In order to introduce more nuance into destabilization studies, there is a need to increase our understanding of the variety of strategies actors utilize to maintain, defend, or disrupt existing institutions, or to create new ones. Another aspect that is largely missing in the destabilization literature is the “human factor”. While actors can employ carefully selected strategies to advance their aims, humans are not always rational and are prone to mistakes. Humans frame issues differently based on the mental models they formulate to make sense of the complex realities surrounding them. Since mental models are prone to distortions and mistakes and can become outdated (Moray, 1999), they can lead to nonoptimal strategies and decisions. Research on mental models in the energy sector is sparse and is mostly from an organizational studies perspective. In transition and innovation studies, mental models are yet to be examined, and we do not know how or if they can influence energy transition and the adoption of sustainable innovations.

This dissertation examines the interplay between actors and institutions, and the resulting influences on energy transitions. It aims to increase understanding of the input of a variety of actors, including those associated with dominant technologies. In order to do so, I examine the current institutional environment in Finland, whose energy system is supported by relatively stable institutions and strong actors (Ruostetsaari, 2010). I explore how institutions can influence the adoption of two climate change abatement technologies: decentralized renewables and CO2 mineralization. These observations are complemented by studying how actors’ mental models, and the strategic institutional work they engage in, can influence their institutional environment. I ask:

1. How do institutions affect technology deployment (CO2 mineralization) and energy transitions?
2. How do actors influence the institutions of energy systems?
3. How can the interplay between actors and institutions influence the direction of energy transitions?

Below, I describe how the research articles included in this dissertation contribute to answering these questions. The first question is addressed in research Articles 1, 2, and 3, while the second research question is explored in Articles 1 and 3. The third research question involves elements from Articles 1 and 2, and will be answered more accurately in the dissertation.

Article 1, Renovation realities: Actors, institutions and the struggle to transform Finnish energy policy, was co-authored with Kamilla Karhunmaa and Sanni Eloneva. This article examines how actors engage in institutional work in order to influence institutional development. We observed the types of institutional work actors engage in to influence energy policy in Finland. We found that, while actors employ several types of institutional work to develop institutional structure, actors’ choices of the types of institutional work they engage in are affected by existing institutions. This interplay between actors and institutions is likely to affect the direction of energy transitions, both through the work done by actors and through the influence of existing institutions on this work.

Article 2, Transition towards a decentralised energy system: Analysing prospects for innovation facilitation and regime destabilisation in Finland, was co-
authored with Sanni Eloneva and Jarkko Levänen. It explores the functional performance of renewable decentralized energy (ReDE) applications in order to analyse the strength and weaknesses of more radical renewable technologies, as well as the drivers of their deployment. The applications we observed were chosen to represent technologies that are unlikely to be aligned with existing institutions. We also included an analysis of the level of destabilization measures that are intended to replace institutions and actors within the energy system, in order to make space for new, sustainable technologies. Destabilization measures occupy a key position in speeding up the energy transition.

Article 3, Opportunities and obstacles for CO2 mineralization: CO2 mineralization-specific frames in the interviews of Finnish CCS experts, was co-authored with Sanni Eloneva, Jarkko Levänen, Arho Toikka, and Mika Järvinen. This article looked at actors’ mental models and how actors frame issues to influence each other and the creation of new institutions. We examined CCGS (Carbon Capture and Geological Storage) and CO2 mineralization to explore how institutions have been created around these relatively new climate change abatement innovations. The article demonstrates that institutions can have significant influence on which applications are considered as solutions. Therefore, they can have significant influence on the deployment of climate change abatement technologies, and place certain applications at a competitive disadvantage.
2. Theoretical framework

In this section, I will build the theoretical framework used in this dissertation, and explore the interconnections between actors and institutions according to the theories used here. Detailed descriptions of the theories and concepts can be found in the three research papers this dissertation is based on, and the purpose of this chapter is to explain the interlinkages between different theories and concepts, and how they contribute to this dissertation. This section will also help in understanding the methodological choices made in the articles. In Section 2.1, I will explore institutional development and institutional change. In Section 2.2, I will look at the role actors play in these processes and how they can influence institutions and the processes of change. In Section 2.3, I will explain the linkages between the different concepts presented in previous sections and their significance for this dissertation.

2.1 The influence of institutions on technological deployment and energy transitions

Energy systems can be conceptualized in different ways, such as technological innovation systems, or fields where actions take place. Regardless of this conceptualization and the theoretical approach, institutions have an integral role in regulating and upholding the system and assuring its functioning. My interest is on the interplay of actors and institutions: how institutions can affect energy transitions on the one hand, and how actors can influence institutions on the other. In Section 2.1.1, I will discuss the role institutions play in energy systems, and how they can influence technological applications. In Section 2.2.2, I will explore both how institutional change takes place at the system level, and the destabilization or lack of destabilization of the existing institutional environment.

2.1.1 Institutions and technological innovations systems

In order to explore the interactions between institutions and actors, we need to examine the current institutional environment these actors are embedded in. The Technological Innovation Systems (TIS) approach can be used to determine the level of support institutions provide to the innovations under observation (Bergek et al. 2008). The technological innovation systems (TIS) framework can
reveal the drivers and obstacles of innovations within the context of the surrounding socio-economic environment (Kivimaa and Kern, 2016). The technological innovations framework was originally developed for the purposes of innovation studies (Bergek et al., 2008), but it has been applied in the field of transition research in order to estimate the deployment of sustainable energy innovations (e.g. Hudson et al., 2011; van Alphen et al., 2009; Praetorius et al., 2010). It provides insight into the performance of innovations, as well as the level of compatibility between innovations and the structure of the surrounding system. In general, TIS is utilized for analysing the institutional environments of individual technologies (Kivimaa and Kern, 2016), but, in this dissertation, TIS is expanded for several small-scale renewable technologies so as to gain a system-level understanding of the institutions affecting energy transitions. A similar approach has been used before by Lukkarinen et al. (2018) to study the cleantech sector.

Technological systems are structures that consist of actors, who perform functions or activities in the system, and institutions that direct these activities; rules, practices, and values (Bergek et al., 2008; Hekkert et al., 2007). The strengths and weaknesses of an innovation system can be evaluated by estimating the level of performance for the following functions: knowledge development and diffusion; resource mobilization; entrepreneurial activity; market formation; guidance of search; and the creation of legitimacy (Bergek et al., 2008; Hekkert et al., 2007). These reveal what factors are driving the development and implementation of the innovation, as well as which factors are slowing down and potentially blocking the innovation (Bergek et al., 2008).

Analysing innovation systems includes mapping their structure, which includes the central actors and institutions governing the system. The Finnish energy system has been relatively stable for decades because the same actors have been at the core of the energy system, which makes it hard for other actors to enter (Ruostetsaari, 2010). This stability means that development is likely to be incremental, with changes building on existing technologies (Article 1), and that radical innovations are unlikely to emerge. However, TIS does not really explain how emerging technologies overturn existing system elements (Kivimaa and Kern 2016). In order to facilitate the emergence of new technologies, and to break free from technological development trajectories, destabilization of the surrounding institutions and other system elements is necessary.

2.1.2 Institutional change: Destabilization or incremental development

An analysis of the functional performance of an innovation and the institutions affecting its implementation (Bergek et al., 2008; Hekkert et al., 2007), when considered in isolation, will create an overly positive picture, and therefore needs to be complemented with an analysis of the level of destabilization (Kivimaa and Kern, 2016). An analysis focused on the functional performance of individual innovations does not include evaluations of the wider institutional environments, such as the institutions, which support traditional technologies. Destabilization can have a significant role in facilitating transitions through cre-
ating space for innovations to enter the energy system. In destabilization studies, destabilization has been defined as the replacement of regime elements (Kivimaa and Kern, 2016; Kuokkanen et al., 2018; Turnheim and Geels, 2012), or, more specifically, regime actors (Normann, 2019).

Kivimaa and Kern (2016) have suggested improving the reliability of TIS analyses by including functions to determine the level of destabilization. These functions include: control policies; significant changes in regime rules; reduced support for regime actors; and the replacement of key actors (presented in detail in Article 2). They provide insight into changes in policy and regime institutions and show the level of support for the regime; whether new actors are entering the system; and whether any significant changes are taking place that would alter the system structure to be more favorable for the innovation in question (Kivimaa and Kern, 2016). According to Bergek et al. (2008), policy has a central role in solving technology lock-ins, and Kivimaa and Kern (2013) list policy as a central determinant in destabilization.

Including these functions offers more insight into the institutional development of the energy system surrounding the technology in question, and provides us with information on what kind of opportunities are opening for these innovations. However, seeing destabilization as displacement of regime elements is a simplification of the complex reality of system transitions, as actors can adapt to changes and become part of the post-destabilization systems (Leipprand and Flaschland, 2018). Furthermore, while technological innovation systems are beneficial in assessing technology deployment in the context of the surrounding energy system, as well as the level of institutional support toward innovations, actions performed by the actors are conceptualized as performing functions to develop an innovation (Bergek et al., 2008; Hekker et al., 2007). Some of these functions deal with policy aspects, such as: creating legitimacy; the guidance of search; and resource mobilization. This conceptualization, however, does not account for the activities actors engage in to influence institutions, policy, and other actors. Policy measures are seen as something that is imposed from the outside and can evolve over time to accommodate innovations, following the actions of policy makers. Therefore, after evaluating the level of institutional support for climate change abatement innovations, using radical renewable energy technologies as a case study, I shifted my attention to the actors and how they influence institutions.

Furthermore, when the level of destabilization of a system is determined to be low (Kivimaa and Kern, 2016), the system can be considered stable. As I mentioned earlier, a majority of literature points to the Finnish energy system being rather stable (Ruostetsaari, 2010, Haukkala 2018), but simultaneously, it has not remained unchanged. Studies show that new interest groups have emerged, and are working together to bring about change in energy policy (Haukkala, 2018).
2.2 Stakeholder perceptions and framings

While system-level institutional analysis is helpful in estimating the level of institutional support to climate change abatement innovations, it does not account for the role of the actors within the system, how actors influence the formation of institutions and how they seek to displace them. Traditional transition studies have been criticized for this lack of attention to actors. Actors can influence institutions through intentional, strategic actions that are targeted to advance their goals, or through the framings they use to communicate with others. Section 2.2.1 explains how actors can directly engage in influencing institutions through institutional work, while Section 2.2.2 describes the influences of actor framings and how actors formulate these frames. The final section (2.2.3) explores how both the frames and the types of institutional work actors engage in can be revealed in actors’ discourses and narratives.

2.2.1 How actors work on transforming institutions

Although recent studies have started to pay increasing attention to agency and actors, they have been criticized for focusing only on the efforts of challenging actors, while overlooking actors who seek to maintain existing institutions (Hess, 2013). It has also been noted that actors’ ability to influence institutions can vary significantly, depending on the national context i.e. institutional stability (Jehling et al. 2019). Actors have preferences in terms of technology choices and policy options, and their efforts to advance these preferences can either support or lead to the displacement of these elements (Kuokkanen et al., 2018). Powerful actors have more resources to influence policy (Avelino and Rotmans, 2009) and can contribute to upholding trajectories. Therefore, they have more influence on the direction and speed of the transition. Evaluating actor influence can be difficult, since extrapolating the influence of individual actors on dynamic and complex processes, such as energy transitions, is very complex (Pesch, 2015). Furthermore, actors create pressures that direct the process in different directions (Rosenbloom et al., 2016; Jolly et al., 2017), and no individual actor can determine the direction of the transition (Berkhout, 2006). Although some actors can be more prominent that others, studies on actors and transitions demonstrate that actors and actor groups work in interaction with each other (Farla et al., 2012), and these interactions are necessary in order for transitions to advance towards their goals.

In this dissertation, an institutional work approach is used in order to assess how actors attempt to influence their institutional environment (Brown et al., 2013; Fuenfschilling and Truffer, 2016; Köhler et al., 2019; Jolly et al. 2016). Actors can aim to maintain existing institutions by recreating, repairing or supporting the mechanisms that uphold these institutions, or they can strive to expand and reconstruct old rules and institutions through creating work (Lawrence and Suddaby, 2006). Actors can also defend existing institutions (Maguire and Hardy, 2009) from other actors who are attempting to disrupt them by eroding and criticizing the mechanisms that make sure actors conform to existing institutions (Lawrence and Suddaby, 2006). The institutional work
framework finds that actors differ from each other based on how much resources they have access to, and actors with more resources have more influence over shaping institutions to fit their interests (Levy and Scully, 2007). Furthermore, as actors seek to influence the institutional structures that surround them, they are also influenced by these institutions in turn (Article 1). Actors’ ability to alter institutions varies according to national contexts. This means that actors who operate in countries with well-established institutional environments can find their choices of institutional work more limited, compared to actors who are attempting to effect change in less established environments (Jolly et al., 2016).

### 2.2.2 How actor perceptions and framings affect policy making

Actors can influence institutions through multiple mechanisms. These include the formation and building of values, practices, and shared ideas, such as mental models. How actors present issues, and formulate problems and possible solutions to these problems through framing, can influence the responses of the actors they interact with. The discourses actors use in discussions can reveal these formulations and ideas, as well as changes in public and actor discourses (Bosman et al., 2014).

Frames depict the linkages between actors’ opinions and the beliefs, assumptions and goals they possess (Schön and Renn, 1994). Framings reveal how actors formulate their message to influence policy and other actors (Entman, 1993), in order to advance what they consider important (Goffman, 1974). Frames can be communicated to other actors and can become institutionalized into policy frames, and directly influence the institutional structures of technological systems (Lenschow and Zito, 1998).

Actors construct their frames through a process of selecting and combining facts, choosing which facts to include and which not to include, according to their values and beliefs (Doyle and Ford, 1998). Actors’ choices about what aspects they emphasize can be conscious or unconscious, but, in essence, they define the problem: how it is interpreted, and evaluated, its causality, and what the potential solutions are (Goffman, 1974). Framings can change an issue significantly (Edelman, 1994), and they vary from one actor to another, indicating that different actors frame the same policy issues differently (Schön and Renn, 1994). Different actors can utilize the same policy measures either to maintain or to challenge existing institutions, depending on the aspects they choose to highlight (Antal and Karhunmaa, 2018). Narratives that do not fit into widely adopted frames can be misunderstood (Gamson, 1992) or can be considered inappropriate, which can lead to these ideas being shut out of policy making (Entman and Page, 1994), or even used to discredit the actor(s) that presented them (Gamson, 1992).

As powerful actors have more influence in energy policy (Levy and Scully, 2007) they are also in a better position to communicate their framing of issues and possible solutions and thereby to affect public opinions (Zaller, 1992). As the powerful actors of the Finnish energy regime have been able to remain stable over decades and represent relatively homogenous group (Ruostetsaari, 2010),
they have been able to uphold a largely stable set of goals. These goals have been reframed to fit the external pressures of climate change and stricter environmental policies, which demonstrates that new policy does not always lead to technological changes, but can result in the creation of new meanings for existing concepts and framings (Kivimaa and Mickwitz, 2011). Powerful actors also have more influence in framing the roles (Huttunen, 2014) that they and other actors are expected to play in the energy system, which are formulated simultaneously with the framing of issues (Laws and Rein, 1993).

Frames can reveal the underlying mental models of actors, which are conceptual representations of a complex reality that make it easier to understand and explain, compared to the system itself (Doyle and Ford, 1998). Mental models affect how actors explain and define complex phenomena, such as technological systems or energy policy, to themselves. Although they are simplifications of the surrounding reality, they are often considered as representative of this reality and guide actors decision making and affect the actions they undertake (de Gooyert et al. 2014). As simplifications of these realities, they are prone to distortions due to oversimplification, omission of facts, non-linear relationships, time delays, and feedback loops (Moray, 1999). Complex new technologies, such as CO2 mineralization are particularly prone to these distortions (Vergragt et al., 2011).

Widely adopted mental models form institutions, as they become internalized into practices and regulations of the field (North, 1990), and thus become guidelines for behavior. This can lead to decision making that rules out technologies as potential solutions and places them in a disadvantageous position compared to alternatives. Mental models in the energy sector have been studied in terms of consumer (Revell, 2015) or company behaviour (de Gooyert et al., 2014). However, there are fairly few studies concerning the effect of mental models on technology deployment (Schmid et al., 2017).

Mental models can be relatively enduring (Doyle and Ford, 1998). Models related to energy technologies are likely to change very slowly and to be highly resistant to change, because energy sectors tend to have centralized structures (van Gooyert et al., 2014). Transforming these resilient images has a vital role in development towards a more sustainable energy system (Sterman and Sweeney, 2007). In this dissertation, I investigate how actors’ framings that have been formulated based on their mental models influence the institutions that guide technological development in the case of CO2 mineralization.

### 2.3 Linking theoretical concepts and frameworks

In Figure 2, I link the concepts and frameworks presented above in the introduction and theory sections (Figure 2). We can begin by observing the sociotechnological system, which is made of system elements, including technologies, actors, institutions, and the functions actors perform within the system. In this dissertation, I examine an ongoing transition and will focus on the interactions between the institutions and actors of a system. Institutions can lead technological development along technological trajectories, which tend to slow
down the adoption of sustainable innovations. Therefore, I will observe the institutions in a stable system, the Finnish energy system, and examine the drivers and obstacles these institutions present for sustainable energy technologies using the technological innovation systems (TIS) framework. In order to chart the transition potential of the Finnish energy system, I include the destabilization functions suggested by Kivimaa and Kern (2016) within my TIS analysis. As actors are not in the forefront in TIS analyses, I will utilize the institutional work approach to analyse the strategic institutional work in which actors engage in order to influence institutions. I also complement institutional observations by looking at how actors’ mental models influence the framings they use in discussing energy issues – an approach which has not been used before for the analysis of energy transitions.

![Socio-technical system diagram](image)

**Figure 2.** Theoretical framework

I am particularly interested in how these interactions influence the direction of the energy transition, although it is worth noting that actors may influence the transition and its direction through other channels as well, such as directly working on new energy technologies. With the top half of Figure 2, the TIS analysis, paired with destabilization functions, I will seek to answer research question 1: How do institutions affect technology deployment (CO2 mineralization) and energy transitions? With the lower half of Figure 2, I explore research question 2: How do actors influence the institutions of energy systems? Then I will combine the results from all three methods of analysis in order to answer research question 3: How can the interplay between actors and institutions influence the direction of energy transitions? The activities actors engage in are based on how they interpret the activities performed by other actors, the surrounding institutional environment, as well as how they frame issues related to the energy system. These framings are communicated to others and can influence institutions as they become widely accepted by other actors.

While actors can influence institutions and institutional development, institutions also affect how actors see the system and frame issues related to it, as well
as the institutional work activities in which they choose to engage. Institutions can be expected to be particularly influential in the presence of technological trajectories, which take place in stable energy systems, such as the Finnish energy system (Ruostetsaari, 2010). Although the institutional context in which energy systems are embedded evolves slowly over time, this process can be accelerated through the destabilization of existing actors and other system elements, such as the institutions themselves. This acceleration is necessary in order to reach the aims that have been set for the energy transition, i.e. limiting global warming to within 1.5 degrees Celsius. What remains unknown is what the technology mix, actors, and institutional environment should look like after the transition. Possibly, there could be several potential outcomes, meaning that several different transition paths are possible.
3. Methodology

In Section 3.1, I will introduce the case studies utilized in this dissertation, the energy transition in Finland and CO2 mineralization, as I explore the institutions that influence their deployment. These case studies were selected to represent the kind of radical innovations that are likely to be incompatible with the existing institutional environment. In Section 3.2, I briefly explain the methods and data, and the analysis performed to analyse the interplay between actors and institutions for these case studies.

3.1 Case studies

One of the aims of this dissertation is to explore technological trajectories and institutions that might favour existing technologies over new innovations. Therefore, the selected case studies represent climate change abatement innovations that appeared incompatible with some of the central institutions in the Finnish energy sector. CO2 mineralization was selected as a case study as it was a marginal technology that contained elements that are novel for the energy sector, namely the chemical process of mineralization of the CO2 on the one hand, as well as finding uses for the resulting minerals on the other. While the process is used in industrial processes, adopting it would require new forms of co-operation. As the process originates from the industrial rather than the energy sector, development and adoption have been slowed down due to incompatibility with existing institutions (Article 3) and would require some institutional adaptation. The second case study was selected to expand these observations beyond the level of individual innovations. It includes observations of a system-level energy transition comprising many small-scale renewable technologies. While the technologies are in different phases of maturity, most are considered to have marginal roles in the energy system (Article 2). In order for these technologies to become mainstream, the destabilization of existing institutions is necessary. To determine the level of institutional obstacles, destabilization measures need to be evaluated in addition to the compatibility with existing institutions. Figure 3 depicts central elements of both case studies in relation to the theoretical framework.
3.1.1 Transitioning the Finnish energy sector

The Finnish energy system can be characterized as centralized because three utility companies control more than half of the market (Energy Authority, 2018). This centralization is due to a long-time emphasis on economies of scale, the aim of which is to maintain low electricity prices (Ruggiero et al., 2015). Affordable energy has been seen as vital to ensure industrial competitiveness (Kerkelä et al., 2014), since energy-intensive industry accounts for approximately 47% of Finnish national energy consumption (Statistics Finland, 2018).

As energy transitions have become the topic of increasing discussion in Finland in the 2010s, new actors have emerged to advocate for the transition (Haukkala, 2018; Article 1). Many of these groups have specified the need to increase the decentralization of the energy system, with a larger share of small-scale, local energy production (Article 2). In addition to reducing CO2 emissions (Motiva, 2010), an increased use of small-scale, renewable, decentralized energy (ReDE) could contribute to the creation of local jobs and economic growth, as well as generating innovation (Halme et al., 2014).

The ways energy is produced and delivered in an energy system are defined by the actors and institutions that form the energy regime that govern the system (Article 2). The Finnish energy regime consists of a relatively small number of powerful actors (Haukkala, 2015) who have been able to retain their positions in the regime for several decades, making it hard for new actors to emerge (Rustetsaaari, 2010). This has led to path dependency (Gronow and Ylä-Anttila, 2016), resistance towards change and resistance to the increased use of renewables (Haukkala, 2015), and renewable decentralized energy (ReDE) in particular (Ruggiero et al., 2015).
Strategically, the importance of increasing the use of renewables has been acknowledged in the national energy and climate strategy (TEM, 2016), although a significant share is expected to come from bioenergy. The background scenarios utilized in the national energy and climate strategy further expects nuclear energy to increase and to play a significant part in the future (TEM, 2016b). The continued commitment to nuclear power demonstrates the dependencies that are prevalent in the Finnish energy sector (Gronow and Ylä-Anttila, 2016). Nuclear energy has been able to retain a high importance, despite having faced many problems and delays in the last decade. From the three reactors planned in the 2000s, Olkiluoto 4 was cancelled (TVO, 2015), Hanhikivi 1 has been delayed prior to construction phase (Fennovoima, 2018), and Olkiluoto 3 is expected to start operation in 2020, which is 11 years after the initial schedule (TVO, 2019a). After completion, Olkiluoto 3 is expected to generate 1600 MW (TVO, 2019b), and Hanhikivi 1 200 MW (Fennovoima, 2019) of electricity.

To investigate energy transition in Finland, we observed the structure and functional performance of ReDE or renewable decentralized energy. We chose ReDE as a case study since it represents radical system change. ReDE applications present a very different business model, compared to the traditional focus on economies of scale and the benefit of centralized energy generation, since they utilize renewable domestic resources (Article 2). We also investigated the institutional work that actors engage in in relation to Finnish energy policy, through the meanings they assign to different aspects of energy policy and the transition (Article 1). While observing the functional performance and the structure of ReDE, TIS will reveal the obstacles and drivers for radical renewable innovations in Finland. Furthermore, the inclusion of destabilization functions (Kivimaa and Kern, 2016) will demonstrate whether changes are taking place in the surrounding energy system to create opportunities for these innovations. Investigating the institutional work that actors engage in includes observations on the interplay between actors and institutions, and it will provide insight on the pressures that actors create to alter institutions and the field of Finnish energy policy.

### 3.1.2 CO2 mineralization and CCS technologies

To observe the influence of actors’ framings, I included an empirical case study of CCGS and CO2 mineralization. At the time we started work on Article 3, a large planned CCGS project in Finland had recently been cancelled (Fortum 2010). Simultaneously, several research groups were developing CO2 mineralization (Article 3), and some were even estimated to be economically viable (Eloneva et al., 2012). As these applications represented a relatively new field, institutions, such as regulation, financial support mechanisms, and industrial practices, were still developing. Considering this phase of technological development, they provided an excellent example to observe actors’ influence on the development of these technologies and the formulation of the institutions that were beginning to be built around these new technologies.
The IPCC has outlined that, in order to achieve the stricter 1.5-degree climate target, the employment of technologies to capture CO2 emissions at source might be necessary (IPCC, 2018). CCUS, or carbon capture, utilization, and storage, involves the removal of CO2 from fuel combustion or industrial processes, transporting it by ship or pipeline, and storing it permanently in geological formations or using it as a resource for products and services (IEA, 2019). According to the IEA, CCUS expected to be particularly significant for carbon – intensive industrial processes, such as cement and chemicals production, steel making, and fuel transformation. More stringent emission targets increase the importance of CCUS in industry as other measures to reduce emissions become exhausted because there are very few technologies available that can directly reduce CO2 emissions from industrial production (IEA, 2019).

While CCGS refers to a CCUS process in which CO2 is stored in underground geological formations (IEA, 2019), CO2 mineralization refers to fixing the carbon dioxide in a silicate mineral, using calcium or magnesium oxide, which then results in a stable carbonate (Eloneva 2010). The mineralization process can also utilize industrial byproducts or waste materials, such as iron slags and coal fly ash (IEA, 2019). This avoids the main problem associated with CCGS, or carbon capture and geological storage: leaks from the storage site. Leaks not only reduce climate change abatement efficiency, but can also pose a danger to humans and animals (Metz et al. 2005). The trade-off of the higher storage safety is the higher economic cost caused by the energy intensity and the large amount of mineral raw material necessary for mineralization (IEA, 2019).

At the time I began to work on this dissertation, CO2 mineralization was in the very early stages of development, and no applications had yet been commercialized (Article 3). According to the IEA (IEAGHG, 2013), the main problems associated with the technology were the lack of technical feasibility and the environmental effects associated with the handling of minerals. In terms of regulation, mineralization was in a difficult position since it was not included as a storage option in the EU CCS directive, since the directive defines CCS as carbon dioxide capture with transportation and geological storage (Zevenhoven and Fagerlund, 2010). Because the same definition was utilized in the EU emission trading system (EU ETS) (EUR-Lex, 2009), mineralization was, by definition, not able to benefit from the economic incentives that were offered to CCGS (Article 3). The fact that CO2 mineralization is not included in emission trading, while CCGS is, lowers the economic profitability of mineralization, making it less competitive compared to geological storage. This is because the exclusion means that investment and operational costs won’t be offset by the sale of unused emission permits.

Since the 2010 CCS project cancellation, it has been noted that CCS with fossil fuels lack potential in Finland, but that there is significant potential for BECCS, in which carbon capture and storage is combined with bioenergy, with the aim of achieving negative emissions (Lehtilä and Koljonen, 2016). The development of BECCS, however, has been slow, and studies show that BECCS has similar deployment issues as CCGS (Fridahl and Lehtveer, 2018). A pilot project for
BECCS has shown that CO2 capture combined with a chemical-looping combustion of biomass (bio-CLC) process can increase power generation efficiency (Pikkarainen et al., 2016). In addition, some CO2 mineralization applications have proven to be financially viable, and at least one project has been piloted (Said 2017). This pilot involved an application for producing PCC from steelmaking slags, an application that allows steel plants to reduce their waste flows by utilizing slag to mineralize their own CO2 emissions (Said, 2017). Despite the relatively high cost of mineralization, this process generates economics benefits from savings in waste disposal costs for the slag and through the production of a marketable end-product: PCC. Therefore, it has the ability to cover the costs of the process, a feature that is missing in CCGS. In comparison with the end-of-pipe-type CCGS process, this application also benefits other processes in reducing the need to produce PCC from virgin materials, contributing to the creation of circular economies (Said, 2017).

Despite the technical and economic potential of some CO2 mineralization applications, the European Commission continues to define CCS as capture, transport, and geological storage, as demonstrated by the quote from the Commission’s website: “CO2 can be stored in geological formations including oil and gas reservoirs, unmineable coal seams, and deep saline reservoirs.” While the Commission does express its wish for increased R&D and demonstration efforts, and aims to increase institutional support, it does not specify what this institutional support would entail (European Commission, 2019c).

### 3.2 Methods

In this dissertation, I examine the effects of institutions on technology deployment, both for an individual abatement technology, CO2 mineralization, and for a system-level change, in the transition towards a more sustainable energy system in Finland. In particular, we look at how actors can influence institutions and institutional development. I sum up these results in estimating the direction of change and the level of current systemic change in Finland.

In Article 3, we analysed actors’ frames on CCS technologies and CO2 mineralization through interviews in order to reveal the underlying mental models, which mould actors’ messages. We also estimated how these frames have affected institutions, and what their influence has been in the deployment of CO2 mineralization.

In Article 2, we analysed the technological innovation system (TIS) for ReDE technologies, which represents radical energy innovations. We estimated the level of support that is provided to them by the current institutions of the Finnish energy system by analysing the structure of the energy system, and we determined the functional performance of the ReDE innovation system, as well as the level of destabilization activities taking place, using indicators (Article 2).

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1 https://ec.europa.eu/clima/policies/innovation-fund/ccs_en
In Article 1, we utilized a discursive approach to explore the actions that actors described undertaking within the system, and the meanings they saw in the actions of others. Their answers were analysed in order to determine what kinds of institutional work they were engaging in.

### 3.2.1 Data Collection

The data sets I used in this dissertation include material obtained from the interviews described above and statistical data collected for the indicators. These data sources were complemented with literature reviews on the structure of the Finnish energy system and the ReDE innovation system, as well as a document analysis on renewables and the energy transition.

This dissertation is based on three interview sets. Interview set I consists of interviews with multiple stakeholders in Finnish energy policy, and interviews sets II and III were conducted with CCS and CO2 mineralization experts (Table 1). Interview set I consisted of 24 interviews with renewable energy stakeholders: politicians, industry, ministries, academics, ENGOs, and citizen activists. In order to ensure a wide representation, we selected several organizations that represented multiple actors. For instance, instead of individual industrial companies, we included industry associations who represented different groups of industrial actors. We charted relevant stakeholders from documentary material, such as actors who had participated in central renewable energy working groups or new actors who had brought forward new ideas and conversations. We used a snowballing technique to ensure that we had covered as many relevant actors as possible and requested each interviewee to name relevant actors they thought we should interview.

Interview sets II and III were conducted to identify framings related to CO2 mineralization and CCS to unveil the mental models related to these technologies. In total, 9 in-depth interviews were performed with stakeholders of CCS and CO2 mineralization in Finland. Some stakeholders were relevant for both CCGS and mineralization, creating synergies between the two interview sets. All actors were interviewed once, and all were asked specifically to weigh in on both applications.

We selected a focus on experts because experts’ opinions have an important role in influencing policy decisions when they concern new and relatively unknown technologies (Hansson and Bryngelsson, 2009). This limitation was also necessary due to the low level of recognition of mineralization; actors who are not working with the technology are likely to be unfamiliar with it. The interviewees were selected to represent all relevant stakeholder groups for both CCS and CO2 mineralization applications, including companies (strategic and operative management), universities, R&D, the government, and the public (ENGOs). Due to the small number of experts in Finland at the time, we were able to include most individuals who had been involved in planning CCS projects. Some interviewees provided us with additional material, such as an environmental assessment report for a planned project. We conducted the interviews anonymously, since only a few companies were involved with CCS projects in
Finland, and mentioning companies would also have made people easily identifiable. Some of our interviewees cited anonymity as a prerequisite to participating in the interviews.

We contacted the potential interviewees by e-mail. Each e-mail contained a short description of the research and the researchers working in it. We were able to interview almost all interviewees who were approached, apart from a couple of politicians who declined the interview request (these actors were replaced by other politicians).

Table 2. Interview data sets

<table>
<thead>
<tr>
<th>Interview set</th>
<th>Technology/Innovation</th>
<th>Actors</th>
<th>Interviewees</th>
<th>Interviewee selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Renewables</td>
<td>ENGOs and citizen activists, industry groups, ministry representatives, politicians, academics</td>
<td>24</td>
<td>Documentary material</td>
</tr>
<tr>
<td>II</td>
<td>CCGS</td>
<td>ENGO (public), R&amp;D, university patent official, government representative, plant leadership, strategic management</td>
<td>6</td>
<td>Charted from planned project</td>
</tr>
<tr>
<td>III</td>
<td>CO₂ mineralization</td>
<td>ENGO (public), researchers, R&amp;D, University patent official, government representative, plant leadership, strategic management</td>
<td>7</td>
<td>Charted from pilot project</td>
</tr>
</tbody>
</table>

To assess the institutional environment of the energy sector in Finland, we utilized a variety of statistical data and other literature (Table 2). Statistics were obtained from various databases offered by national funding organizations, the IEA, the National Office of Patents and Registration, as well as data compiled from searches performed in the Science Direct website. Other literature included government documents, ranging from laws and regulations, official strategy publications to working group reports and the scenarios that were used as a basis of these reports. Scientific publications, online statements and professional journals published by stakeholders, as well as programme evaluations and funding decisions from national funding organizations whose data we used to complement the official statistical data. More detailed description of the data can be found in Article 2. Generally, technological innovation system analyses have combined these types of data with stakeholder interviews, but we found sufficient data to analyse 1–3 indicators for each function, which we felt was sufficient as the purpose was to gain an idea of the institutional environment, rather than to perform a detailed analysis of the functions.
Table 2. The data used to analyse the Finnish energy system (adapted from Bergek et al., 2008; Hekkert et al., 2007; Kivimaa and Kern, 2016)

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government documents</td>
<td>Ministry of Employment and the Economy report on decentralized renewables</td>
<td>Publications and dedicated journals; Expectations/growth potential; Public procurement; Inclusion of new actors</td>
</tr>
<tr>
<td></td>
<td>National climate and energy strategy</td>
<td>Expectations/growth potential; Restrictive policies; Legal reforms that change the structure of the system</td>
</tr>
<tr>
<td></td>
<td>Climate and energy strategy scenarios</td>
<td>Restrictive policies and regulation; Legal reforms that change the structure of the system</td>
</tr>
<tr>
<td></td>
<td>Ministry of finance report</td>
<td>Removal of subsidies and tax deductions</td>
</tr>
<tr>
<td>Scientific publications</td>
<td>Viilola and Heljo 2012; Heiskanen et al. 2017</td>
<td>Government support for research, testing and demonstration</td>
</tr>
<tr>
<td></td>
<td>Heiskanen et al. 2017</td>
<td>Market size and drivers</td>
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<tr>
<td></td>
<td>Haukkala 2015</td>
<td>Rise and growth of interest groups</td>
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<tr>
<td></td>
<td>Ruostetsaari 2010b; Gronow and Ylä-Anttila 2016</td>
<td>Inclusion of new actors</td>
</tr>
<tr>
<td></td>
<td>Haukkala 2018</td>
<td>Formation of new organizations and networks</td>
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<td>Data bases</td>
<td>Science Direct database</td>
<td>Publications and dedicated journals</td>
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<tr>
<td></td>
<td>Academy of Finland (AKA) funding database</td>
<td>R&amp;D projects and funding schemes; Government support for research, testing and demonstration</td>
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<td></td>
<td>Tekes funding database (currently Business Finland)</td>
<td>R&amp;D projects and funding schemes; Government support for research, testing and demonstration</td>
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<td></td>
<td>International Energy Agency (IEA) Data Services</td>
<td>Government support for research, testing and demonstration; Cuts in R&amp;D funding</td>
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<td>Patent and Registration Offices (PRH) database</td>
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<td>Actor statements, publications</td>
<td>Wind Power Association magazine</td>
<td>Publications and dedicated journals</td>
</tr>
<tr>
<td>Funding decisions and project documents</td>
<td>Academy of Finland New Energy Programme 2015–2018</td>
<td>R&amp;D Projects and funding schemes; Government support for research, testing and demonstration</td>
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<td></td>
<td>Tekes Final evaluation of the DENSY programme</td>
<td>R&amp;D Projects and funding schemes; Government support for research, testing and demonstration</td>
</tr>
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</table>
Table 2. The data used to analyse the Finnish energy system (adapted from Bergek et al., 2008; Hekkert et al., 2007; Kivimaa and Kern, 2016) (Continued from previous page)

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<th>Data</th>
<th>Source</th>
<th>Indicator</th>
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<td></td>
<td>Tekes SHOK-CLEEN Smart power grids launch</td>
<td>R&amp;D Projects and funding schemes; Government support for research, testing and demonstration</td>
</tr>
<tr>
<td></td>
<td>Tekes Intelligent Energy Programme launch</td>
<td>R&amp;D Projects and funding schemes; Government support for research, testing and demonstration</td>
</tr>
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<td>Laws and regulations</td>
<td>Customs guide</td>
<td>Regulation and financial support mechanisms</td>
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<td></td>
<td>Tax Information table</td>
<td>Regulation and financial support mechanisms</td>
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<td></td>
<td>Ministry instructions on energy support</td>
<td>Regulation and financial support mechanisms</td>
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<td>Government resolution</td>
<td>Public procurement</td>
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<td>Public procurement guideline</td>
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<td></td>
<td>Law on compensating indirect costs of emission trading (Law 138/2017)</td>
<td>Removal of subsidies and tax deductions</td>
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<tr>
<td>Other</td>
<td>Work Efficiency Society (TTS) report on heat company profitability</td>
<td>Government support for research, testing and demonstration</td>
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<td></td>
<td>Finnish Clean Energy Association publication (FCEA) on growth in heat pumps</td>
<td>Government support for research, testing and demonstration; Market size and drivers</td>
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<tr>
<td></td>
<td>FCEA publication on increased employment opportunities with SMEs working on renewables and energy efficiency</td>
<td>Human resources: education and expertise</td>
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<tr>
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<td>Publications of Heat pump association and Heat entrepreneur’s association</td>
<td>New entrants</td>
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<td>Energy company publications</td>
<td>Companies diversifying</td>
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<td>Producer association publications; heat entrepreneurs, small hydro</td>
<td>Market size and drivers</td>
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<td>Statements from organizations advocating for renewables</td>
<td>Expectations/growth potential; Rise and growth of interest groups; Alignment with legislation; Inclusion of new actors; Formation of new organizations and networks</td>
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<td></td>
<td>Association membership</td>
<td>Rise and growth of interest groups</td>
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</table>
Table 2. The data used to analyse the Finnish energy system (adapted from Bergek et al., 2008; Hekkert et al., 2007; Kivimaa and Kern, 2016) (Continued from previous page)

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green Cultural Association report on energy transition</td>
<td>Alignment with regulation</td>
</tr>
<tr>
<td></td>
<td>Institute for Economic Research (VATT) report on energy subsidies</td>
<td>Removal of subsidies and tax deductions</td>
</tr>
<tr>
<td></td>
<td>EU Commission news</td>
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</tbody>
</table>

3.2.2 Analysis

The research interviews were analysed based on actor discourses, an approach that can be useful in identifying structural changes in the energy system as they are taking place or only beginning (Kuokkanen et al., 2018). The language that actors use reveals the rules, standards, and beliefs that actors uphold and the meanings they assign (Fuenschilling and Truffer, 2016). Therefore, discourses offer a way to investigate the institutional work that actors engage in, as well as how they frame issues.

All interview material was recorded on tape during the interviews, with the approval of the interviewees. The interviews were then transcribed by an independent company, coded and read iteratively by 2–3 researchers. For interview sets 2 and 3, the codifications were compared and discussed and classified into categories along with relevant citations. We used these as a basis to identify six frames from the material. The transcripts for data set 1 were read and coded using atlas.ti (atlas.ti 8 Windows) separately by three researchers. We organized the codes into an excel sheet by themes and analysed the types of institutional work.

In addition to the interviews, we performed a technological innovation systems (TIS) analysis. First, we explored the structure of the energy system based on a literature review. Then we analysed the functional performance of ReDE technologies using indicators. We compared the functional performance with Germany and Denmark in order to benchmark the result and to estimate the level of performance as high or low. We selected these countries because they have been considered as frontrunners in the energy transition and the use of renewables (Halme et al. 2014), and they are considered to be further along in the energy transition that other countries. It also meant that there were studies available that estimated the performance of the innovation systems in these countries. These studies also provided us with information on which aspects were most significant in improving functional performance and supporting the energy transition in these countries. We selected the indicators according to the suggestions made by Bergek et al. (2008) and Hekkert et al. (2007) and applied them for our study. We also included indicators suggested by Kivimaa and Kern (2016) to estimate the level of destabilization activities. The indicators we used
for each function, and their detailed descriptions, can be found in Article 2. We utilized between 1–3 indicators for each TIS function.
4. Results

In the introduction I presented three research questions:

1) How do institutions affect technology deployment (CO2 mineralization) and energy transitions?

2) How do actors influence the institutions of energy systems?

3) How can the interplay between actors and institutions influence the direction of energy transitions?

In this section, I will endeavour to answer these questions based on the results analysed in the research articles. First, I will explain the results related to how institutions affect the deployment of CO2 mineralization and ReDE, as well as the advancement of the energy transition in Finland. Then, I will explore the institutional work that actors engage in, as well as the influence their mental models can have on institutions and technological development. Finally, I will sum up the results of the three articles by evaluating the current level of systemic change in the Finnish energy system and the direction of this transition.

4.1 How do institutions affect technology deployment (CO2 mineralization) and the energy transition?

The Finnish energy regime is formed by powerful actors and the institutions whose formation they have influenced, has remained stable, making it exclusive and difficult for new actors to enter the system and to gain influence within it (Ruostetsaari, 2010a). Due to the exclusivity of Finnish energy policy, the importance of analysing destabilization by assessing current and planned policy measures, and the level of institutional change brought on by new actors, is heightened (Article 2). Results from Articles 2 and 1 support previous literature in that the same actors have been able to retain powerful positions and have more influence in the system. This can be problematic for innovations that are not compatible with the existing institutions, such as CO2 mineralization and ReDE. They’re both seen as marginal technologies (TEM, 2014; IPCC, 2013), and thus the expectations are not high. Regarding CO2 mineralization, the IPCC special report (2013) states: “Industrial uses of captured CO2 as a gas or liquid or as a feedstock in chemical processes that produce valuable carbon-containing products are possible but are not expected to contribute to significant abatement of CO2 emissions. The potential for industrial uses of CO2 is small.”, while
the national climate and energy strategy frames ReDEs as a marginal, exportable product (TEM, 2014).

Low expectations about the potential of these applications leads to a low level of legitimacy (Article 2; Article 3). This low legitimacy means that they are not really considered as options in decision making. The lack of legitimacy is solidified in other formal and informal institutions. Since the EU CCS directive and the EU ETS, CCS has been defined as CCGS, effectively excluding CO2 mineralization (European Commission, 2019). This exclusion from ETS places CO2 mineralization at a competitive disadvantage financially, while its exclusion from regulation further reinforces its lack of legitimacy (Article 3). Similarly, ReDEs fall below the minimum size requirement for Finnish renewable tariffs and installations have been slowed down due to permission procedures that varies according to municipality (Article 2; Salo, 2015). This lack of institutional support reduces the financial viability of ReDEs compared to competing technologies, although there is indication that the support is improving; a tax relief has been established for ReDEs that are below the tariff size limit, and the Finnish research funding organizations have funded research programmes to study ReDE (Article 2), as well as research projects on CO2 mineralization research and development (Luoma et al., 2017).

The lack of legitimacy and the framing as marginal applications are also reflected in the informal institutions surrounding CO2 mineralization (Article 3), as their effect can be seen in defining CO2 mineralization as CO2 utilization (GHGT-11, 2013). As this definition has been accepted by most of the actors, mineralization studies have been marginalized to CO2 utilization journals and conferences, and excluded from important CCS conferences and journals (Gale, 2013), where they are less likely to catch the attention of the CCS community. Results from Article 3 demonstrate a lack of institutional support for CO2 mineralization, and the majority of the frames we obtained from the interviews of CCUS experts were negative.

Our results from Article 2 showed that the institutions of the Finnish energy system have developed to facilitate large-scale energy generation (Ruggiero et al., 2015), and do not support the implementation of decentralized renewables. For the ReDE technologies we analysed, most functions, notably knowledge development and diffusion, mobilization of resources, entrepreneurial activity and market development, looked very encouraging (functions and descriptions in Article 2). Despite the increased activity in developing and adopting these technologies, our results showed the guidance of search to be problematic, as it framed ReDEs as an exportable cleantech product, reducing legitimacy. This interpretation of ReDE technologies is not surprising when considering the institutions of the Finnish energy system, which I discussed in Section 3.1.1. Against the backdrop of a long-term focus on the creation of economies of scale and affordability, small-scale production would appear inefficient and high cost compared to traditional options.
4.2 How do actors influence the institutions of energy systems?

Actors’ influence on institutions is complex and multifaceted (Article 1), and actors differ in their abilities to influence institutions and transitions. Many studies have outlined that actors with strong positions in the system, i.e. regime actors, have more influence over policy and institutional development (Avelino and Rotmans, 2009). In the Finnish energy system, a group of core actors have maintained their positions in the system for decades (Ruostetsaari 2010) and have close connections to the government, ministries, and the ruling parties (Gronow and Ylä-Anttila, 2016). In addition to official co-operation, actors have formed unofficial, personal relationships (Gronow and Ylä-Anttila, 2016), which have resulted in some of the decision making taking place “behind closed doors” (Ruostetsaari, 2010). This was mentioned by some of our interviewees for the second interview set (Article 1), who described some of the decision making taking place before the official hearings.

In Article 3, we found that most of the actors’ mental models of CO2 mineralization and the frames associated with them had a negative impression of the future of CO2 mineralization. The influence of the negative frames are visible in the institutions, in part because half these frames, namely, high-cost, and immature technology, represent the views of the interviewees who were CCGS experts, whereas all positive frames were put forward by CO2 mineralization experts. This implies that the CCGS experts are in a more powerful position to communicate their frames to decision makers and the public, consistent with Zaller (1992). Article 1 demonstrates that powerful actors also have more ability to define the roles of other actors, as well as themselves. Industrial actors in Finland have taken on an expert role in energy policy that is also recognized by decision makers. Novel actors attempting to take on new roles have been criticized for overstepping their roles, and for lacking institutional accountability by the more powerful actors we interviewed. This can limit new actors’ possibilities to disrupt the existing roles and institutions of energy policy.

Looking at the frames and mental models we discovered in Article 3, we can see that the actors representing mainstream applications (CCGS) had a much more negative outlook on CO2 mineralization, and represented half of the negative frames that were related to the high cost and the immaturity of mineralization applications. The two positive frames were formulated by mineralization experts and see opportunities in the weaknesses of CCGS and in the features that are missing from CCGS: the large CO2 storage potential and the lack of geological storage in Finland. In this sense, the two are seen as competing optional storage methods. While CCGS is the norm, CO2 mineralization has certain advantages compared to CCGS. This positioning of the two as in competition with one another was implicated strongly in the results of our interviews. The other negative frames (false definition of CCS, and unsupported by the CCS community) refer to obstacles that are formed by the views of other actors. The lack of support by the CCS community is connected to the false definition frame in the sense that excluding CO2 mineralization from the definition of CCS delegitimizes it as a CCS method and as a CO2 abatement method. This delegitimization
effectively leaves it outside the selection of possible solutions that are considered when looking at abatement options, which demonstrates how framing defines the potential solutions that can be considered as solutions for the issues that are under consideration. The interviewees often referred to frames relating to the technological aspects (immature technology, and high cost) of mineralization to explain the low level of legitimacy, although these aspects may change following future technological development. In the interviews, this potential is only referred to by actors who are working with CO2 mineralization, while actors involved in CCGS did not remark on it.

In article 1, we utilized the institutional work framework to analyse how different actors attempt to influence the Finnish energy transition and which way their actions are steering the direction of the transition. We found that actors described themselves as utilizing all the institutional work types, and as attempting to maintain, disrupt, and defend existing institutions and participate in the creation of new ones (Lawrence and Suddaby, 2006; Maguire and Hardy, 2009). Detailed descriptions of actors’ approaches can be found in Article 1. Actors emphasized their engagement in creative institutional work, while supporters of renewables appeared to avoid disrupting activities, and traditional actors downplayed the maintaining and defensive work they performed. The results indicate that all actors, including those who are advocating for renewables, are under pressure to comply with the existing institutional environment (Article 1). This affects their choices of the institutional work they engage in, and can even keep actors from engaging in disrupting institutional work.

Our findings demonstrate that actors can influence the institutions that direct technology deployment through intentional, strategic work, as well as through how they frame issues and possible solutions. While the mental models these frames are based on can be formed partially unconsciously, the framing used to communicate them can become formalized into institutions. While actors can influence the institutional structure of the energy sector, they are also directed by it. Due to these structures, some activities are more acceptable that others, which limits the options that are available to actors who are attempting to promote marginal technologies, or who are advocating for the energy transition. Evidence from Article 1 shows that actors who do not comply with existing institutions can have difficulty in being taken seriously; powerful actors have questioned the facts that these actors have presented, and attempted to delegitimize them.

Finland has a tradition of consensus politics (Salo, 2014), which emphasizes the pressure to comply with institutions and highlights co-operation with other actors (Article 1). Therefore, employing disrupting strategies in consensus oriented, stable systems, like Finland, is particularly difficult. Efforts to disrupt existing institutions are further complicated by the different ways actors interpret the aims of the energy transition. In Article 1, we found that while all actors share the idea that we should move towards a carbon-neutral energy system, they have different interpretations regarding carbon neutrality. While the newer actors would like to see a system based on 100% renewables, many of the powerful actors include nuclear power in their definition of carbon neutral. These
conflicting interpretations can complicate discussions and further discredit disrupting institutional work.

4.3 How can the interplay between actors and institutions influence the direction of energy transitions?

Our interviewees from interview set I were asked about the energy transition in Finland and they generally agreed that the transition was in its very early stages, while some of them believed it hadn’t really started yet (Article 1). This is supported by our findings in Article 2, which demonstrated that, despite the increased functional performance of ReDE technologies, the level of destabilization is low. Therefore, institutional change has remained modest, and, despite the creation of new institutions to support renewables, we found that the institutional support for existing technologies is not being reduced. This indicates that a transition is likely to take place slowly and be based on incremental changes building on existing structures. The result could be simply a decarbonization of the existing system, rather than a genuine systemic transformation.

Article 2 also showed that there is a low level of regime destabilization; while activities surrounding renewables have increased, and new actors have entered the system, our analysis of the destabilization functions (Kivimaa and Kern, 2013) clearly shows that no significant systemic changes are taking place. Institutional support for regime technologies in the form of reduced financial support and the introduction of restrictive policies or regulation are not likely; on the contrary, support for regime technologies had increased significantly since 2012 (VATT, 2016; FINLEX, 2017; EU Commission, 2017).

Our results from Article 2 indicate that an analysis of the functions of the innovation system alone can give overly optimistic assessments of the openings that are available to innovations in the energy sector. We found a lack of institutional support for ReDEs despite the increasing activity, but we also found that some policy measures had been introduced that were targeted to ReDE technologies. This would indicate that, although the current level of institutional support was low, it was strengthening, and our national comparisons with the German and Danish ReDE innovation systems indicate that higher legitimacy tends to follow.

The introduction of new actors might initialize a process of eroding the legitimacy of regime technologies (Kivimaa and Kern, 2016). Article 1 shows that new actors are being included in policy-making processes by invitation to give statements to policy working groups (FCEA, 2016b), although regime actors still hold more powerful positions as permanent members in these working groups (TEM, 2014; FCEA, 2016b). The results from these articles show that, currently, the energy transition in Finland is not driven by policy, but by increased activity within the private sector, and by novel actors that are entering the system. Their influence has remained low, however. Although institutional support for ReDE appears to be increasing, it is somewhat offset by the continued and increasing support for regime technologies, which are maintaining the stability of the energy system and the energy regime.
The national comparison we performed in Article 2 showed that, in Germany and Denmark, which are considered positive examples of energy transition, the change has been driven by policy, both in terms of strong guidance of search to promote ReDE technologies, and in terms of pushing towards destabilization. Although the transition has not been progressing without problems in these countries, the development has been in line with the TIS framework, where policy is highlighted in overcoming path dependencies and accelerating transitions. In Article 1, we discovered that most actors participate in creating institutional work, and actors emphasize their creating activities, while downplaying other aspects, such as defensive or disrupting work. Many new actors made a conscious decision to avoid disrupting strategies in order to address the aspects that were most likely to gain results. All actors agreed on the importance of achieving a carbon-neutral energy system, and, while their interpretation of carbon neutral as well as preferred policy differed, these findings demonstrate that, despite that lack of destabilization (Article 2), incremental changes have taken place (Article 1).
5. Discussion

The aim in this dissertation has been to examine the interactions between actors and institutions, and how their complex relations influence technological deployment and energy transitions. The interest has been on both the competition between technological applications and system-level energy transitions. I have limited my observations to Finland, a country where the energy system has remained relatively stable (Ruostetsaari, 2010), and destabilization policies are largely missing. This dissertation demonstrates that actors can influence institutions through their strategic involvement in institutional work, and through their framings of energy issues. Furthermore, the types of institutional work they engage in, as well as the framings they formulate, can be significantly influenced by the surrounding institutional environment.

In this section, I will discuss these connections between actors and institutions in a wider context, and explain the contribution and the limitations of this dissertation and the articles it is based on.

5.1 Institutional obstacles and institutional change

In the introduction, this dissertation set out to explore the institutional environment facing sustainable innovations in Finland; how this environment influenced actors; and how actors, in turn, influence their institutional environments. To evaluate this, I started by charting the drivers and obstacles of sustainable innovations (Article 2). Despite the increasing institutional support for sustainable innovations, and new policy measures to support them, adoption of sustainable innovations has been driven by actors (households and companies) (Article 2; Heiskanen et al. 2017), which highlights the importance of studying actors and how they influence transitions.

In addition to this, we found that EU-level regulation can be harmful to the adoption of some sustainable innovations in member states (Article 3), as was demonstrated by the case study on CO2 mineralization. According to the framings that were discovered in Article 3, due to the industrial structure and lack of geological storage, Finland should be focusing on mineralization, instead of CCGS. However, EU level institutions place mineralization at a disadvantageous position compared to CCGS, and do not provide the necessary incentives to deploy these technologies. These findings are supported by Kauto et al. (2012), whose study on biomass use made similar observations regarding conflicting national policy and the EU ETS, and found this to have a significant influence on what extent renewable technologies are employed.
On the other hand, national institutions can also weaken the effectiveness of EU-level institutions, for instance, by reducing the EU ETS permit price (Perthuis and Trotignon, 2014). An example of conflicting national policy from the case studies employed in this dissertation is a law implemented in 2017 to compensate companies for the costs incurred by emission trading permits (FINLEX, 2017). As companies will not bear the true cost of their emissions, they will not invest in abatement technologies, which results in higher emissions and reduced effectiveness of the emission trading programme.

According to Kivimaa and Kern (2016), a TIS can give an overly positive image if it is not paired with an estimate on the level of institutional destabilization. The results of this dissertation support their conclusion (Article 2). The results indicate a low current level of destabilization policies, and strong institutional support for traditional technologies. In the case of energy-intensive industry, financial support has been increased with recent policy measures. This is detrimental to the competitiveness of sustainable innovations, and undermines the increased policies directed to support sustainable technologies (Article 2).

In general, TIS is used in the analysis of individual technologies (Suurs and Hekkert, 2009; Jacobsson and Bergek, 2011). In this dissertation, TIS has been used to analyse institutional support for small-scale renewables. Some examples exist where TIS has been expanded to include multiple applications (Lukkarinen et al., 2018). Although the results from an analysis of multiple technologies do not provide accurate results for each individual application, they have been able to provide a system-level view of the drivers of small-scale renewables, as well as of the level of destabilization policy. Kivimaa and Kern (2016) demonstrated that traditional TIS analyses can provide an overly optimistic picture of transition potential, as they ignore the institutions which uphold the existing energy system. Our results from the analysis of the institutions of the Finnish energy system, performed in Article 2, confirm this finding. The addition of destabilization functions by Kivimaa and Kern (2016) provide a much wider perspective into the TIS of small-scale renewables in Finland. Despite positive developments in the institutions that surround sustainable innovations, we get a much bleaker view as we take a step back and observe the changes taking place in the wider institutional environment. The virtual lack of destabilization policy could indicate strong technological path dependencies.

The Finnish energy system has a well developed institutional structure, and the level of institutional change has been low (Ruostetsaari, 2010; Haukkala 2018). Actors’ abilities to influence institutional development have been influenced by the very institutions they seek to alter (Article 1), and the lack of significant destabilization policies (Article 2) indicate the existence of a technological trajectory. While actors from the interview sets considered climate change an important issue, this importance has not really generated significant changes in energy policy.
5.2 Actors

Since the amount of destabilization policies is low, the changes that are occurring are actor driven, incremental changes, targeted at the creation of new institutions. Stable energy systems can be characterized as having an exclusive regime of central actors (Article 2, Ruostetsaari, 2010), who have been able to maintain their powerful positions for long periods of time. This makes it difficult for new actors to emerge and to influence institutions. In systems with exclusive actor regimes, these powerful actors are better positioned to influence policy and institutions. Thus, they have the ability to define the roles that actors should abide by (Article 2), as the actions that actors engage in are influenced by the existing institutional environment, and they appear to favour strategies that comply with surrounding institutions (Article 2).

Despite shared aims, actors may have different visions of how those aims should be achieved, and may employ a multitude of strategies to reach them. The embeddedness of actors in the existing institutional framework ensures that actors’ choices will be, if not limited, at least directed by the surrounding institutions. Actors’ mental models are reflected in the framing they utilize to describe and communicate issues to each other. As such, mental models can be reflected in institutional surroundings and even become solidified into policy measures. These policies are then directly influencing the technological development and adoption of sustainable innovations and, through that, have the potential to influence the energy transition.

The results presented in this dissertation indicate that even challenging actors are more restricted by the existing institutional structure than we have previously thought. The actions they participate in, or feel they can participate in, in order to be successfully able to influence energy policy, are limited by the institutional environment they exist in, as well as by the activities undertaken by other actors. Engagement in activities that powerful actors would consider inappropriate or unrealistic, or overreaching their institutional roles, can undermine their ultimate goals through the defensive action of other actors. This should not be considered as a malignant attempt to slow down the transition, but more as a natural reaction from the other actors, who are simply seeking to defend their position in energy policy. While more controversial approaches can initiate new discussions, they have not been truly integrated into policy making processes in Finland and have not necessarily been given genuine consideration (Article 1). This can result in solidifying the marginalization of an application, technology, or actor within the institutional structure.

The results from Articles 1 and 3 demonstrate that actors can influence institutions intentionally through institutional work, but also in a more indirect way, with the framings they utilize to explain issues and justify actions and policies. De Gooijer et al. (2014) demonstrated the strong link between mental models, framing and strategic action. The frames they use to communicate to others, as well as the activities they engage in to influence the energy system, further influence the reactions of other actors. Actors can also frame elements of the existing energy system. Article 1 shows how different actors have framed the aim of the energy transition in Finland, despite the shared overall goal of carbon
neutrality. While some actors view it as 100% renewable, others are willing to include nuclear and/or bioenergy. These interpretations affected the types of institutional work the actors were engaged in, and is likely to influence the resulting formation of new institutions. As we presented in Article 3, and as I discussed in the results section of this dissertation, actors’ framings have had a significant influence on the development of institutions related to the technology deployment of CO2 mineralization and CCS, both in Finland and at the EU level. They can become solidified into the institutional environment, which could reinforce path dependencies or slow down implementation (as in the case of CO2 mineralization). Once it has been integrated into the institutional environment, it becomes difficult to change and can reinforce technological trajectories. This highlights the importance of destabilization in energy systems with exclusive regimes.

Evaluating the influence of actors can be difficult, since extrapolating the influence of individual actors on dynamic and complex processes, such as the energy transition, is very complex (Pesch, 2015). Furthermore, actors create pressures that direct the process in different directions (Rosenbloom et al., 2016; Jolly et al., 2017), and no individual actor can determine the direction of the transition (Berkhout, 2006). Although some actors can be more prominent that others, studies of actors and transitions demonstrate that actors and actor groups work in interaction with each other (Farla et al., 2012), and these interactions are necessary in order for transitions to advance towards their goals.

Institutional work is well suited to analysing the strategic action individual actors engage in, as it allows us to map actor strategies according to the direction of their institutional influences; whether actors aim to maintain, create, challenge or defend existing institutions. However, extrapolating the influence of individual actors on dynamic and complex processes, such as the energy transition, is very complex (Pesch, 2015). The multiple connections and influences between actors and institutions, explored in this dissertation, demonstrate the difficulty of translating these multiple connections into estimations of future transitions. Framing can be used to reveal sometimes unconscious mental models, but individual statements that represent radically different views from other actors, can gain a lot of weight in the analysis in comparison to the more “mainstream” views. While this can be useful in revealing problems with widely accepted models, they can also lead to distorted simplifications of the reality similar to the mental models themselves, unless researchers make sure to take into account the background and affiliation of the individuals behind the frames. In a context of assessing two competing applications, such as CO2 mineralization and GCCS in this dissertation, the radical views are more likely to provide a more detailed image of the institutional conflicts faced by marginal innovations.

5.3 Limitations

Our first interview sets, II and III, were limited to interviews with a total of nine CCGS and CO2 mineralization experts (Article 3). The sample was therefore rel-
atively small, and some experts such as politicians were represented in both interview sets, since they could be considered as experts for both CCGS and CO₂ mineralization. This inevitably means that individual statements have a large influence on the results. For example, as we described in Article 3, the frame false definition of CCS was based on the statements of two interviewees who saw the definition of CCS as CO₂ capture followed by transport and eventual geological storage as problematic. This means that there were also differences between the strength of the six frames we discovered; while some (e.g. high-cost and immature technology) were supported by all or nearly all interviewees, other were less well supported. However, these issues are a consequence of the immaturity of CO₂ mineralization technologies. Due to the early development phase, the technology was, and still remains, relatively unknown, even in the CCS community. While conducting our interviews, we discovered that many professionals who were working with CCGS had rather limited knowledge of CO₂ mineralization. They knew what it was, but many remarked that they could not really present estimates on its future development as they were not familiar with the technical and financial aspects. Therefore, most of the more detailed material on CO₂ mineralization came from the mineralization experts. In order to increase the strength of the frames and our results, we would have had to first educate the interviewees on CO₂ mineralization, which could risk us unintentionally influencing their views. While our choice not to educate our interviewees resulted in a small sample for the mineralization-specific frames, it also provided a genuine representation of the framings of CCGS experts and how their mental models of CO₂ mineralization affected these framings. If the interviews had taken place five years later, as the technology was becoming better known, the respondents would have likely been more familiar with it.

TIS analyses are often based on interviews and supplementary document analysis (e.g. van Alphen et al., 2009; Praetorius et al., 2010; Hudson et al., 2011). We chose not to utilize interviews as there was plenty of documentary material and statistical data available. We were also able to build on previous studies conducted on the drivers and obstacles of ReDE in Finland. Research interviews could have potentially increased the reliability of the findings by integrating stakeholder views; they could have also provided us with more details about expected future development. However, in the context of our analysis on the institutional support on ReDE deployment and the current level of destabilization in the Finnish energy system, the additional benefit provided by interviews would have been limited. Our decision to analyse several technologies together provides us with an analysis of the ReDE innovation system as a whole, but the data is not sufficient to conduct a detailed analysis of the individual technologies that were included in the study. Therefore, our results should not be used to draw technology-level conclusions, but should rather be taken as an indication of general development.
6. Conclusions

This dissertation examined the interaction between institutions and actors in a stable institutional environment. The technological innovation system (TIS) framework was used to analyse the drivers and obstacles for sustainable innovations, and this analysis was expanded with an examination of the level of destabilization policy, aimed at displacing existing institutions that support other energy sources. To assess the influence of actors, two approaches were used. The institutional work framework was used to investigate the strategic work actors engage in to maintain, defend, challenge or create institutions, while an exploration of framings revealed actors’ mental models of sustainable innovations.

The analysis was based on case studies observing energy transitions and the adoption of sustainable innovations in Finland. Three interview sets and a documentary analysis were conducted in order to estimate actors’ influences, while indicators built using data obtained from databases, statistics, and literature were utilized for analysing TISs. The results demonstrated the complex interaction between institutions and actors. While actors can influence the formation of new institutions and challenge or maintain existing ones, the activities they engage in are limited by these institutions. While additional policy has been developed to support sustainable technologies, their adoption is mostly actor driven. Institutions created on an international level, like the EU, can be incompatible with national conditions and institutional environments, weakening policy effectiveness. Actors’ mental models can influence institutional development through their framings and lead to the strengthening of technological trajectories. The lack of destabilization policy, as well as the existence of significant support for traditional technologies, point towards a strong path dependency and a stable institutional environment.

These results indicate that a radical energy transition unlikely and point towards a decarbonization of the existing system, with the institutional environment and powerful actors remaining the same. Studies show that there is a significant gap between the necessary emission reductions and the existing levels of emission reduction measures. In order to meet the Paris Climate Agreements aim of limiting warming to 1.5 degrees, Finland would need to implement much stricter emission reduction measures (Sitra, 2016). According to estimates, Finland should reduce CO₂ emissions by 60% by 2030 and between 130%–150% by 2050, compared to 1990 levels (Rocha et al., 2016).
The political will to achieve this appears to exist, since it has been announced that Finland aims to become carbon neutral by 2035 (Finnish Government, 2019), and would strive to be the first industrial nation to achieve negative emissions, soon after 2035 (President of the Republic of Finland, 2019).

The results from Article 2 demonstrated that the increased use of renewables is driven by households and entrepreneurs, not by policy, and the level of destabilization is low, while policies aimed at destabilization are largely missing. This indicates that both policy efforts to support abatement technologies and implementing destabilization policies to remove support for existing technologies would facilitate the transition.

The European Union Emission Trading System (EU ETS), for example, featured strongly in the results of all three interview sets used in this dissertation, indicating that actors place high importance on the mechanism. However, all actors in our interview sets discussed some weaknesses with the programme. The low emission permit prices, and the exclusion of CO2 mineralization were noted as some of the most significant reasons why the EU ETS had not been successful in supporting the implementation of new emission reduction measures. Although the EU has made some efforts to address the level of permit prices by removing permits from the market, the effect of these efforts remains unclear (Burtraw and Themann, 2018). Furthermore, continued financial support to maintain low energy costs for energy intensive industry further reduces the efficacy of the EU ETS; removing this support through destabilization would aid in improving its effectiveness and can be employed at the national level.

Similarly, national level policies could be implemented in order to correct the institutional incompatibility caused by EU policy. Implementing a financial support mechanism to substitute the financial disadvantage caused by the exclusion of CO2 mineralization from the EU ETS could improve the competitiveness of these technologies, and lead to reductions in industrial CO2 emissions. These reductions are important in a country like Finland, where the largest point source of CO2 is a steel plant generating 7% of annual CO2 emissions (Energy Authority, 2019).

While the results from Article 1 demonstrate that measures have been taken to open policy processes and to include novel actors (renewable supporters and those advocating for an energy transition) in decision-making, it also showed how much stronger the positions of traditional actors are. While a wide variety of actors’ voices are heard in policymaking, industrial actors are still invited to serve as permanent experts in ministry working groups. As they are seen as experts by ministry representatives, and they have more influence over policy outcomes than other actors. Interview set 1 revealed that many renewables supporters felt that decisions were being made behind closed doors, even prior to the official hearings with stakeholders. The formation of these working groups should be diversified, in order for all actors to have real influence in their outcomes.

Further exploration into the extent to which actors’ choices about how to engage in influencing energy policy are limited by the existing institutional envi-
rformance is necessary. While this dissertation demonstrates that stable institutional arrangements are likely to influence actors’ choices, and a study by Jehling et al. (2019) suggests that institutional constraints are more prevalent in developed nations with well-established institutional arrangements, we do not know much about the magnitude and mechanisms of these influences. While Article 1 uncovered some of the institutions that have been particularly influential in the Finnish context, these are likely to vary according to national contexts. Comparative studies involving different national settings could provide more detailed information.

Other areas for further research efforts could include the efficiency of various policy mechanisms in promoting climate change abatement technologies and destabilizing existing regime elements: particularly overcoming stable institutions and the limitations they impose on actors’ efforts to disrupt the system. The policy mixes need to be tailored to fit the institutional contexts in different countries, and to fit EU policies to national conditions, in order to cover areas that are considered marginal at the EU level, despite their higher significance for specific member states.

As energy transitions progress, actor framings on energy issues, and the mental models these frames are built on, are likely to evolve. Changes in mental models, however, remain an understudied area. An increased understanding of how mental models can be changed could aid in removing limitations to disrupting institutional work. Also increasing actors’ awareness of their mental models and how they influence actors’ framing of issues and the institutional work they engage in, would help actors to recognize their mental models and adjust them when necessary. This would benefit incumbent actors in particular, as enduring mental models have been shown to be based on historical preferences and past experience (de Gooyert et al., 2013), which can be harmful as actors strive to keep up with changing institutional and operational environments.
References


References


References


