Currents of Change

Actors, policies and market design in an advancing energy transition

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Preface

This PhD thesis marks the end of a long and sometimes very strenuous journey. One important reason that I managed to land it was the invaluable support of my two supervisors. Markus Bugge, you have provided thorough and inspiring comments in decisive phases of this PhD and encouraged me to pursue my own ideas. Elin Lerum Boasson, you challenged me to assess my work from a broader theoretical perspective and especially helped me to shake the fourth – and in my view the most important – paper of this thesis into shape. I have truly enjoyed our discussions and I am sincerely grateful to both of you.

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Articles in the Thesis

1. Marie Byskov Lindberg, Jochen Markard, Allan Dahl Andersen. 2019. Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix. Research Policy. Vol. 48 (10).

2. Marie Byskov Lindberg. 2019. The EU Emissions Trading System and Renewable Energy Policies: Friends or Foes in the European Policy Mix? Politics and Governance, Vol.7(1), pp.105-123

3. Marie Byskov Lindberg, Lorenz Kammermann. The rise of the *nigime*? An assessment of advocacy coalitions in an advancing energy transition. Manuscript submitted for review.

4. Marie Byskov Lindberg. The power of power markets: How do zonal market designs comply with advancing energy transitions? Manuscript submitted for review.

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Summary

Against the backdrop of sustained calls for strengthened climate policy, the energy transition is increasing in dynamics and scope. Renewable energy is expanding rapidly worldwide, in particular within the electricity sector. During the past two decades, several (new) renewable energy technologies have moved from commanding negligible shares of the market to constituting a significant part of the European electricity supply. Most of these renewable technologies, especially wind energy and solar PV, differ from conventional energy sources, in that their production is variable and less predictable. To accommodate for increasing shares of renewable energy production, the configuration of the electricity sector needs to change.

This thesis is situated within the nascent field of sustainability transition studies. It investigates the implications of the European energy transition for key actors, policies and the configuration of the electricity system. For this purpose, it draws on theoretical perspectives from innovation studies, political science and social science more broadly. In particular, it mobilizes the multi-level perspective, the advocacy coalition framework and institutional theory.

The European transition in the period 2013 to 2018 is used as a case to explore what happens when a sustainability transition advances. This is a very interesting period since renewable energy technologies are becoming increasingly competitive and reaching higher market shares. Within the transition literature, this is denoted as "the third phase of the transition", also known as the diffusion or acceleration phase.

The thesis is composed of four research articles and an introductory part. The three first papers have in common that they take a close look at the preferences and policy beliefs of key stakeholders in EU electricity policy. This is used to gather information about the potential directions of the transition, the EU's policy mix and to show how an advanced transition leads to new constellations in the policy system. The first paper explores how the energy transition can take different pathways. It combines an assessment of the EU's policy mix and the preferences of key actors to show how actors try to steer the transition in their preferred direction. Building on these insights, the second paper takes a closer look at the policy mix for the energy transition in the EU. Paper 3 identifies the main advocacy coalitions in the electricity policy system and discusses how coalition boundaries have changed along with the advancing transition. The fourth paper takes a slightly different perspective and assesses how existing market designs comply with the ongoing reconfiguration of the electricity system that follow from the energy transition.

The thesis provides three main insights. First, it shows that different sustainability transitions pathways are possible. It identifies the trend toward increasing decentralization versus continued centralization as embodying competing pathways within the EU's policy mix. Notably, incumbent actors favor centralized technologies and configurations, whereas environmental organizations and new entrants prefer decentralized options. The directionality of transition pathways is closely related to the actors' business models, financing opportunities and technological competences.

Second, the relationship between markets and policies shifts in the third phase of the transition. In a short space of time, certain actors have changed their policy beliefs and preferences. This is especially true for incumbents that have entered into niche technologies. However, the thesis also documents a change among the protagonists formerly considered niche actors. As the niche technologies become more mainstream, several niche actors are moving away from primarily advocating for niche protection and nurturing. Instead, increasing attention is devoted to changing the configuration of the regime. This can above all be observed within the wind industry, which is the largest renewable

electricity source in the EU. The thesis documents how the maturing niche and progressive utilities are approaching each other through similar policy preferences and beliefs.

Third, the thesis provides new insights as to the role of market design. As costs for renewable technologies decrease and support schemes for niche technologies become less important, market design is turning into a key issue for succeeding with the energy transition. The fourth paper establishes a framework for assessing the compatibility of zonal market models with the energy transition. Even though the EU has a strong vision for a harmonized European energy policy, electricity market designs vary considerably across member states. Electricity market design has large implications for what kind of infrastructure we have and how it is utilized. The thesis shows how market design can simplify the integration of RE by increasing flexibility and bringing system costs down.

Together, the four studies show that the unfolding energy transition is characterized by a high degree of change. The thesis contributes to transitions theory and the multi-level perspective by documenting how these changes manifest within the policy system, the policy mix and market design. To policy science, the thesis shows how policy studies would benefit from explicitly considering technological change to a greater degree. Policy makers and stakeholders could use the findings to better understand the effects of different policies and market designs, which hopefully would lead to improved solutions and help the energy transition advance further.

1 Introduction

1.1 Policies and markets in advancing sustainability transitions

The challenge of climate change is urgent and demands immediate action. Analyses show that in order to stay below 1.5°C, the energy sector needs to fully decarbonize by 2050 (Schleussner et al., 2016). Since the 1990s, the EU has responded to the calls of climate scientists with emissions reduction goals and renewable energy (RE) targets. Even though current targets are insufficient in light of the need for rapid decarbonization of our economies (IPCC, 2018; UNEP, 2019), these targets define the frames within which climate policy instruments are developed. Indeed, they are important stepping stones on the way forward.

Concurrent with efforts within climate policy negotiations, the ongoing energy transition is increasing in its dynamics and scope. Renewable energy is expanding rapidly in the global energy mix driven by a range of different developments. These include falling technology costs, technology development and improvement, ambitious public policy in many countries and regions, an active civil society and a large 'green' research community (REN21, 2017). Above all, the dynamics of technological development are a result of *policies* (Schmidt & Sewerin, 2017). Public policies for renewable energies comprise both policy targets and various types of support (Rogge & Reichardt, 2016).

The expansion of renewable energy is particularly prominent in the electricity sector. Due to the nature of electricity generation and the presence of viable zero-carbon options, the sector is often highlighted as the first and easiest one to decarbonize (IPCC, 2014). The electricity sector is characterized by high deployment levels of so-called 'new' renewable energy; wind power and solar PV. With increasing adoption of these new technologies, their price-performance ratio is gradually improving (Sandén & Azar, 2005).

The overarching objective of the thesis is to understand how the role of policies and markets changes in an advancing energy transition. This transition is an area of tremendous development (see chapter 5) and is therefore of particular interest to transitions scholars. I have been especially interested in understanding how actors react and reorient confronted with these changes, and how their policy preferences shape the future direction of the transition.

The thesis uses the European energy transition as a case to explore what happens when a sustainability transition advances. What happens when niche technologies gain increasing market shares, their cost levels decrease, and new types of actors engage with these technologies? The main entrance points for exploring this advanced phase of the transition are a) public policies and the relationship between market and regulatory policy approaches, b) the policy preferences and strategies of key stakeholders in the policy system, and c) electricity market design and the configurations of the technical system.

Within the nascent field of *sustainability transition studies*, the multi-level perspective (MLP) has been developed and applied to understand the processes and system dynamics that unfold when new innovations and technologies take hold and gradually win through against established technologies (Elzen, Geels, & Green, 2004; Geels, 2002). This body of literature conceptualizes sustainability transitions as large-scale and non-linear systemic shifts where one socio-technological regime is replaced by another (Berkhout, Smith, & Stirling, 2004; Geels, Elzen, & Green, 2004; Verbong & Loorbach, 2012).

Transition scholars describe the advancement of a transition as a set of consecutive phases (Geels, 2019; Verbong & Loorbach, 2012). Starting with experimentation and testing of new technologies in phase 1, these innovations stabilize into a dominant design in phase 2 (Geels, 2019). In the third phase, the deployment of radical innovations accelerates, and eventually the new technologies diffuse into mainstream markets. This leads to thorough changes and a reconfiguration of the socio-technical system. As a result, phase 3 has been denoted in various ways. Verbong and Loorbach (2012) call it the "reconfiguration or acceleration phase" whereas Geels introduced the description "diffusion and disruption phase" (Geels, 2019). In phase 3, niche innovations challenge the existing regime in a completely different way than previously. As a result, this phase is characterized by struggles on multiple dimensions (Geels, 2019).

A large number of studies have provided important insights into the first stages of a transition when new and more sustainable niche technologies start growing and acquire increasing shares of the market (Berkhout et al., 2004; Geels, 2002; Kemp, Schot, & Hoogma, 1998; Smith & Raven, 2012). They have identified market protection and nurturing as key measures for enabling and promoting new and more sustainable technologies. Although existing studies have provided important insights about the first phases of a transition (Köhler et al., 2019), we know less about the advanced phases of *sustainability transitions*.

A key characteristic of sustainability transitions is that they are mainly policy driven (Rogge, Kern, & Howlett, 2017) and initiated because of planetary boundaries (Rockström et al., 2009). As such, they differ from *technological transitions*, i.e. transitions that are not coupled to sustainability. Historical studies of technological transitions have shown that they mostly happen because of technological superiority and progress (Geels, 2002, 2005). In order to ensure further upscaling of the energy transition, by contrast, state intervention and various types of policy instruments will continue to play a role. However, the type of state intervention in advancing transitions might differ substantially from that of the transition's early phases.

The energy transition is a sustainability transition within the energy sector which is primarily driven by *climate policy*. Historically, climate policy development has been characterized by a tension between market-based approaches on the one hand, and regulation and technology development on the other (Boasson & Wettestad, 2013). Since the adoption of the Kyoto Protocol in 1997, the main strategy of large, influential companies and industries has been to advocate broad, cross-sectoral and market-based measures like GHG emissions trading (Meckling, 2011; Skjærseth & Wettestad, 2008). In the transitions literature, many studies have shown that the distribution of authority between markets and government is an important reason for contestation in the early phases of sustainability transitions. Contrasting these market-based approaches, actors engaging with niche technologies, so-called *new entrants*, advocate regulation and technology support in order to strengthen and shield the new niches from market forces. The incumbents – also called *regime actors* (Geels, 2014) – pursue various strategies to maintain their positions in the socio-technical system. Some regime actors oppose policies, claiming that these distort the market and should be avoided. Instead, technology support should primarily take the form of research and development (R&D). If technology support is given, it should as a minimum be market-based and *technology-neutral* (see Azar and Sandén (2011) for a discussion on technology neutrality).

However, as the transition advances, new constellations evolve. When niche technologies gain increasing market shares, it spurs change in the entire socio-technical system, including in the policy subsystem. Whereas several studies have documented how incumbents pursue various strategies to resist change, more recent studies find that incumbents, confronted with ongoing transitions, might chose alternative strategies (Berggren, Magnusson, & Sushandoyo, 2015; Steen & Weaver, 2017; van Mossel, van Rijnsoever, & Hekkert, 2018).

Given that the new technologies have different properties than the existing ones, the energy transition requires a reconfiguration of the socio-technical system. This entails change in several aspects of the system, including where electricity is produced and how it is transported and stored. Even though there is increasing attention toward the need for system reconfiguration (IST, 2018; McMeekin, Geels, & Hodson, 2019), the role of *electricity market design* has not yet been an explicit part of this. Consequently, there is a lack of studies that investigate system configuration and market design from a social science perspective within the context of the energy transition. Scholars have argued that we need more in-depth studies of the nature, origins and evolution of the detailed technical rules and procedures that enable complex technological systems to operate (Bolton, Lagendijk, & Silvast, 2019). This is essential to understand systemic change in the third phase of the energy transition.

1.2 Research questions

Guided by the motivation for studying the implications of an advancing energy transition, as presented above, this thesis asks:

How do policies, markets and actors' preferences change in the third, advancing phase of energy transitions?

The research question entails an inquiry of how the change invoked by the ongoing transition unfolds in different parts of the socio-technical system. A primary aim is to understand the role of policy and markets sustainability transitions and how these roles change when the transition advances. This includes an investigation of how market-based and regulatory policy approaches affect the transition and how different policies interact in the policy mix. The thesis invites an investigation of what constitutes the third phase of the energy transition as suggested by the theoretical perspectives.

The thesis explores some of the main lines of conflict within the EU's energy and climate policy in the current phase of the transition. This helps identify the main issues at stake and informs about the potential directions of the transition. An important endeavor is to assess the policy preferences of key stakeholders in the policy system with respect to different policy and market approaches. Further, the thesis examines different electricity market designs and how they comply with the ongoing transition.

Finally, am interested in how the insights derived within the thesis about the role of policies, markets and actor preferences can be translated from the empirical cases to more abstract theoretical contributions. In order to find theoretical and empirical answers to the overall research question, I carry out four individual studies. A common denominator for the four individual studies is that they shed light on the relationship between markets and policies from different perspectives. Further, they seek to capture how this relationship changes in the third phase of the energy transition. The four studies, with their individual research questions, are listed in table 1.

Table 1: Papers and individual research questions

Paper nr	Paper title	Research question
1	Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix	***Which policies and which actors favor which kind of sustainability transition pathway in the EU's energy policy mix?***
2	The EU Emissions Trading System and Renewable Energy Policies: Friends or Foes in the European Policy Mix?	***Why do different actors hold substantially different policy preferences toward the ETS and RES support – and are these preferences consistent across policy processes?***
3	The rise of the *nigime?* An assessment of advocacy coalitions in an advancing energy transition	***What are the main coalitions within EU electricity policy and how can coalition structures inform transition scholarship?***
4	The Power of Power Markets: How do zonal market designs comply with advancing energy transitions?	***How do zonal electricity market designs differ and what are the implications for the energy transition?***

Given that there are very few successful examples of truly sustainable transitions in the world (O'Brien, 2018), the transitions literature is still underdeveloped when it comes to describing the role of policies and markets in *advanced* sustainability transitions. Further, transition theory is short of tools for adequate assessment of policy processes within transitions. Therefore, transition scholars have recommended engaging with policy theories to understand the politics of sustainability transitions (Kern & Rogge, 2018). When it comes to market design and regulation, scant attention has been devoted to this issue within the transition literature. Despite the alleged importance of markets in ongoing energy transitions, we lack good conceptualizations of markets as key institutional structures within socio-technical systems.

Although transition studies and the MLP in particular are good at describing the overall dynamics in a transition, they often mobilize other tools and theories to explain concrete phenomena. Numerous studies have employed theories from other social science disciplines that can fruitfully cross-fertilize the various dimensions of transition studies, including organization theory (van Mossel et al., 2018), institutionalism (Andrews-Speed, 2016; Fuenfschilling & Truffer, 2014), management studies (Lieberherr & Truffer, 2015), science and technology studies (Silvast, 2017) and various strands of public policy theory (Kern & Rogge, 2018; Normann, 2015).

In order to answer my research questions, the four papers in this thesis apply several theories and different methods. I employ deductive as well as inductive approaches. The papers are strongly 'grounded' in a broad array of data (Corbin & Strauss, 2015). At the same time, I develop propositions and expectations from existing theories and literature. Above all, I mobilize established theoretical approaches from public policy, including from the Advocacy Coalition Framework (Jenkins-Smith, Nohrstedt, Weible, & Sabatier, 2014; Sabatier, 1998) and institutionalism (Scharpf, 2000; Scott, 2001; Thelen, 1999).

The thesis breaks new ground by developing a framework for assessing electricity market designs and their compatibility with energy transitions. This is important for two main reasons: First, market design is crucial for further upscaling of the energy transition and will become a key issue when RE subsidies are increasingly cut back, and second, the theory for exploring market design within transition studies is largely underdeveloped. In order to assess the different types of electricity market designs in Europe, I evaluate a large body of techno-economic literature on European electricity market design. This is a novel and important contribution, both to the transition studies literature and to the broader research community for social energy research.

Further, the thesis employs a novel methodological framework which involves a mathematical representation of policy preferences and beliefs. This is a valuable tool for illustrating the main causes of contestation among a large number of actors. Combining this with quantitative techniques enables a more refined assessment of the main coalitions and distinctions between actors in the policy system. As such, this is a fruitful way to examine the most important tensions and controversies in policy mixes. The importance of assessing such policy tensions has been singled out as an important research agenda within innovation policy and the policy mix literature (Flanagan, Uyarra, & Laranja, 2011).

My main empirical object of analysis is the European energy transition. The empirical studies in this thesis cover the period 2013-2018. This was the period when the EU negotiated its "Clean Energy Package for all Europeans" (CEP), which was adopted in 2018 and 2019. CEP entails many new and amended policies that have significant implications for the European energy transition, including RE support, the role of grids infrastructure and system configuration. Partly in parallel with the CEP process, the EU carried out a reform of its Emissions Trading Scheme (ETS), with several amendments adopted in the period 2015-2018. The empirical context for the thesis is elaborated further in chapter 5.

In the first three papers, I have assessed consultation responses from key stakeholders to the European Commission, in which they express their policy preferences and positions regarding policy instruments and the direction of the energy transition. The main methods in these papers consist of a structural analysis of these responses complemented by 15 qualitative interviews and a document analysis of other written material. In the first paper, I compare the policy preferences of actors with a policy mix assessment based on a detailed review of EU electricity policy documents. The second paper assesses the consistency of policy preferences across three different policy processes. Paper 3 uses consultation responses to identify advocacy coalitions within EU electricity policy.

The fourth and last paper takes a slightly different focus in that it assesses electricity market design in two European regions: The Nordic countries and Germany. Hence, this paper compares electricity regulation on the national or regional level. The assessment builds primarily on interviews and a comprehensive document analysis of technical reports, consultation responses and other publicly available documents.

Eventually, the findings from all four papers are used to inform sustainability transition theory and the MLP in particular. The thesis also provides several insights that are highly relevant for public policy and techno-economic studies of electricity systems. The thesis shows the large potential for cross-fertilization of transition studies with more established disciplines and theories, especially public policies. However, it also makes explicit that social science scholars of energy transitions must understand the financial and regulatory aspects of existing energy regimes in order to identify the main drivers and barriers for the transition (Loorbach & Verbong, 2012). This requires thorough engagement with the techno-economic literature. Combining both types of knowledge under the umbrella of transition studies, the thesis provides several important insights about the ongoing energy transition.

1.3 Overview of papers

Table 2 provides an overview of the four papers in the thesis, their units of analysis, theoretical approaches and main contributions.

Table 2: Overview of the papers within the thesis

	Topic	Unit of analysis	Theory	Main contribution / findings
Paper 1	Competing sustainability transitions pathways in EU's energy policy mix	Key stakeholders' policy preferences for the energy transition and EU's electricity policies. The dichotomy between centralization and decentralization in the three main components of the electricity system: production, grids, system operation	Sustainability transitions theory: MLP Theory on 'Policy mixes'	There is an increasing tension between increasing decentralization within production, but strong centralization within grids and system operation. We find more disagreement about the direction of the energy transition than whether it should take place at all.
Paper 2	Main tensions within EU's energy policy mix	Identifies policy preferences of five groups of actors across different policy processes regarding the relationship between key policy instruments in the EU's policy mix: the EU's ETS and RE Directive.	Theory on 'Policy mixes' Institutional theory	Policy preferences differ substantially between groups of actors with respect to whether the two instruments are perceived as coherent and consistent. Preferences remain stable across policy processes for most groups of actors. The utilities group stands out as the group where preferences vary across policy preferences.
Paper 3	Advocacy coalitions within EU energy policy	Key actor coalitions assessed through policy beliefs and degree of cooperation. Identifies coalition dynamics and discusses implications for transitions theory.	Sustainability transitions theory Advocacy Coalition Framework	Coalitions in EU energy policy become more fluid in phase 3 of the energy transition. We identify the formation of a new regime; the *'nigime',* advocating improved markets and strong state intervention. Some overall distinctions between niche and regime levels still prevail.
Paper 4	Electricity market design in advanced energy transitions	Wholesale electricity market design and bidding zone configuration in Germany and the Nordic electricity market. Assesses implications of different market models for the energy transition.	Sustainability transitions theory (MLP); whole-system perspective Institutional theory	Electricity market designs vary substantially across the EU. Market designs influence all components of the electricity sector, i.e. system operation, grid design and management in different ways.

The thesis is structured as follows. Chapter 2 presents the theory applied within the thesis. A key focus is on transitions theory and the MLP, which is the theory applied to interpret the overall findings of this thesis. Further, chapter 2 elaborates on the role of different types of policies for sustainability transitions and introduces the two main theories for explaining policy processes applied in the thesis, i.e. institutionalism and the advocacy coalition framework (ACF). Chapter 3 describes the research design and methods applied in the four individual studies. Chapter 4 presents the empirical context for the studies in this thesis, namely the European energy transition and EU energy and climate policy. The main findings based on the article collection are presented in chapter 5. Chapter 6 discusses the implications of these synthesized findings for transitions theory, before chapter 7 summarizes and concludes.

2 Theory

This thesis is situated within the nascent field 'sustainability transition studies'. The multi-level perspective (MLP) is considered as one of the key theoretical frameworks within this field, and this theory is employed to assess the overall findings of the thesis. A key objective of the theory section is therefore to account for this framework, its origins and main contributions. I also elaborate on some of its shortcomings, especially when it comes to the state-of-the-art theory for phase 3 of a transition, which is the main focus of this thesis. The chapter starts with a brief introduction – in section 3.1 – to innovation studies which prepared the ground for key concepts and insights of the MLP. Section 3.2 presents the sustainability transitions literature and niche and regime concepts and boundaries. Given my overall objective to study an advancing transition, I discuss the implications of maturing innovations in the third (i.e. diffusion) phase of a transition. Resulting from the increasing market shares of niche innovations, there is an increasing need for system reconfiguration in phase 3. This is discussed as a distinct feature of advanced sustainability transitions. In section 3.3 and 3.4, I elaborate on the role of policy and politics. Section 3.3 discusses the strand of literature denoted the 'politics of transitions' and introduces the two main theories for explaining policy processes applied in the thesis, i.e. institutionalism and the advocacy coalition framework (ACF). Section 3.4 pays particular attention to different policy approaches and their relevance for sustainability transitions in the third phase.

2.1 Innovation Studies

Given that the field of sustainability transitions is still young, it is still considered part of its 'mother discipline', namely that of innovation studies. Before I embark on the discussion of transitions theory, I will take one step back and examine the origins of the innovations field. After all, transition studies stands on the shoulders of the innovation discipline and many of the key concepts within transition literature derive from innovation scholarship.

2.1.1 Schumpeter's theory of innovation

The Austrian economist Joseph Schumpeter (1883-1950) is widely recognized as the "founding father of innovation theory" (Edler & Fagerberg, 2017, p. 4). He studied the different economic theories at the beginning of the 19th century and developed his own theory about the immanent forces in an economic system. Later this was labeled as a specific strand of economics, called 'evolutionary economics' (Fagerberg, 2003). His ideas and contributions have nevertheless inspired scholars in a variety of disciplines. Most prominent though is probably the impact of his theories and conceptions about innovation, the dynamics of innovation processes and the importance of innovation for economic growth and development. To understand Schumpeter's innovation concept, it is important to understand his work on the economic system.

Schumpeter's economic theory is a *dynamic* theory, as opposed to the static perception of a market equilibrium assumed by the neoclassical economists. Schumpeter disagreed with the idea of a market in which demand and supply is regulated 'by the invisible hand of the market'. Instead, he argued that the supply-demand equilibrium is constantly disrupted, due to innovation (Fagerberg, 2003, p. 129).

Schumpeter was the first scholar to introduce a theory of innovation (Edler & Fagerberg, 2017). He distinguished between invention and innovation, which emphasizes the difference between a new product or material (i.e. a new idea), and the process and endeavor of either implementing this product into practice or combining different products in new ways. In other words, Schumpeter stresses the social aspect of innovation, as something which is carried out within an economic (or social) system (Fagerberg, 2003, p. 131). The rationale for this distinction was that an invention does not matter much unless it is exploited in the economic and social system (Edler & Fagerberg, 2017, p. 4). Kline and Rosenberg later pointed out that it is actually *during* the exploitation process that much of the amelioration (i.e. innovation) takes place (Kline & Rosenberg, 1986). Therefore, *innovation policy* should address both the process of initiating new solutions (products, processes, system reconfigurations) and their diffusion – i.e. their implementation into real-life practice.

2.1.2 The concept of a technological regime

Schumpeter recognized that a variety of factors at the individual, group and social level influence the ability to innovate (Fagerberg, 2003). These factors also influence the resistance in society toward innovation. Above all, actors that profit from an existing system will be reluctant to embrace change. However, in order to provide space for new products and ideas, old ones need to vanish. Later, these ideas were further developed and gave rise to the notions of 'technological regime' and 'niche'.

The idea of a basic or dominant design has been important in the innovation literature. Scholars have studied and identified regularities in technological change and the interplay between social practices and technological change. Two concepts that describe these phenomena have been highly influential. The first is the concept of a 'technological regime' by Nelson and Winter (1977), which argues that technology is developed within a specific framework, in which the actors share a common outlook. Due to the established practices within confined social systems (e.g. firms, universities), actors will only focus on optimizing the production within the frames of a given regime. The second concept is that of a 'technological paradigm' (Dosi, 1982). It relates to Nelson and Winter's regime concept in several ways. First, it perceives the actors involved as constrained by a specific set of technologies (or artefacts) and a set of search heuristics (or engineering approaches) that guides their way forward. Second, this set of technologies and heuristics will not only determine the methods for solving specific problems, but also frame the scope of action with respect to 1) which problems to solve, 2) where these research activities lead them and 3) the type of knowledge utilized (Dosi, 1982).

Kemp et al. (1998) developed the technological regime concept further and advocated a broader understanding of the concept. In their view, a technological regime encompasses not only the artefact and the paradigmatic framework of researchers and engineers, but the whole system built around a specific technology, including production and distribution systems, consumption patterns and maintenance practices[1]. The main elements of the technological regime are *the rules* in the wide sense, including commands, requirements, roles and practices. Much of the restriction for socio-technical change is hence explained by the fact that existing technologies are embedded in "broader technical systems, in production practices and routines, consumption patterns, engineering and management belief systems, and cultural values" (Kemp et al., 1998, p. 182). This creates economic, technological, cognitive and social barriers for new technologies. Their assertion is that this confines technological change much more than a lack of engineering imagination.

The concept of a technological regime helps explain why most technological change is incremental and not radical. The latter implies changes in both supply and demand structures. Most companies would rather improve existing technologies than develop something new, which would potentially threaten their existing business models. Radically new technologies more often meet resistance. Moreover, when introducing new, more sustainable, technologies, the task is not only to promote a single technology, "but to change an integrated system of technologies and practices" (Kemp et al., 1998, p. 184). This becomes all the more important in later phases of a transition, which I discuss in subsequent sections.

[1] They suggest the following definition for 'technological regime': "the whole complex of scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology" (Kemp et al. 1998, p. 182).

2.2 Sustainability transitions literature

The literature on transitions has its origin in the innovation literature and describes the process of shifting from one technological regime to another (Kemp, 1994). Later contributions included changes in user practices and institutional arrangements, which led to the term *socio-technical transitions* (Geels, 2004a). Within the literature on sustainability transitions, this has been expanded to include the *sustainability* dimension. As the term suggests, this implies that the transition involves a shift toward sustainable technologies and practices. A common definition of *sustainability transitions* is provided by Markard, Raven, and Truffer (2012, p. 956): "Sustainability transitions are long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption".

2.2.1 The MLP framework

Geels introduced the term 'Multi-level Perspective' (MLP) to denote an analytical framework for analyzing socio-technical transitions (Geels, 2002). The MLP perceives transitions as regime shifts, which are brought forward through a dynamic process characterized by struggles between the socio-technological regime and a niche. Niches are defined as spaces that shield experimental projects with radical innovations from harsh selection pressures from incumbent regimes, nurture radical innovations through the provision of resources, and empower such innovations to press for institutional change in incumbent regimes (Smith & Raven, 2012).

Evidence from history shows that niches have played an important role in developing and upscaling new technologies. In many cases, the military has created such niches through spending money and establishing a market for radical technologies, such as radio, aircraft and computers (Kemp et al., 1998). Niches have provided a protected space for new emerging technologies through 1) demonstrating the viability of a new technology, 2) providing financial means for further development, 3) helping to build a constituency behind a new technology, and 4) initiating learning processes and institutional adaptions. The deliberate process of niche formation has been termed *strategic niche management* (Kemp et al., 1998, p. 184-186). Insights from this literature identify three processes as crucial for niche development: learning, network building and articulation of expectations (Geels, 2011).

One main contribution of the MLP is that it adds a landscape level to the niche- and regime levels in the socio-technical system, and that it describes (potential) interactions between the different levels. The landscape level accounts for external factors, such as economic crises, natural catastrophes or international agreements, which eventually influence the regime level. The MLP explores the dynamics between these three levels within historical and ongoing transitions and includes elements such as the timing of events and the nature of interaction. Geels has carried out several studies where he shows the usefulness of these concepts when studying historical technological transitions (Geels, 2002, 2004b, 2005).

The MLP has been very important for the field of sustainability transitions and numerous contributions have applied or elaborated the MLP (Köhler et al., 2019). Although the framework was developed to analyze transitions as such (Geels, 2002, 2005), it has mainly been applied on different case studies for *sustainability* transitions. Moreover, scholars have suggested ways to improve and expand on it (e.g. Belz, 2004; Fuenfschilling & Truffer, 2014). Some important studies have shown how incumbents engage in niche technologies, suggesting the need to revisit the dichotomous approaches between the different levels and the idea that new entrants will always stand against incumbents (Berggren et al., 2015).

Indeed, the existing definition of transitions as a 'shift in socio-technical regime' is very broad and opens up for different interpretations. The literature offers little concrete advice on what it takes to spur, facilitate or enable sustainability transitions. Instead, this has been elaborated in specific terms in case studies. Kivimaa (2014, p. 1371) noticed that although the existing literature highlights difficulties in destabilizing existing socio-technical systems and in niches breaking into mainstream, "it is rather obscure about what concretely needs to happen".

2.2.2 Transitions dynamics and up-scaling

Inherent in the MLP framework is a description of the transition dynamics. Geels has depicted the MLP in his illustrations which shows the dynamic movement between the niche, regime and landscape levels (e.g. Geels, 2002; 2007; 2011). Figure 1 shows one of the early illustrations of the MLP from 2004. The six angles (and arrows) of the regime represent the different regime *types* that are coordinated by the socio-technical regime. In section 2.3.2 I account for these regime types and their interlinkages in more detail.

Later illustrations of the MLP distinguish between four *phases of a transition*, see Figure 2. Each phase has its own core activities and struggles. I will here only give a brief account of key features in phases 1, 2 and 4 and devote more attention to phase 3, which is the focus of this thesis. Phase 1 is the experimentation phase, where radical technologies are tested in laboratories and demonstration projects. Phase 2 is when the innovation technology is stabilized into a dominant design. Market niches play an important role in learning and standardization and establishing best practices.

The third phase describes the process which is most relevant for this thesis. Geels terms it the *diffusion phase* and it is driven by internal and external drivers:

> In the third phase, the radical innovation diffuses into mainstream markets, on the one hand driven by niche-internal drivers such as price/performance improvements, economies of scale, development of complementary technologies, and support from powerful actors, and, on the other hand, taking advantage of structural windows of opportunity created by landscape developments that pressure the regime, leading to tensions and regime destabilization. (Geels, 2019, p. 6)

Other transition scholars have called this phase the *reconfiguration or acceleration phase* (Verbong & Loorbach, 2012, p. 10). In this phase, elements of the old regime and novel elements are combined to form a new dominant regime. This implies that the niche threatens the regime in a completely new way. Therefore, phase 3 is characterized by myriad struggles on multiple dimensions. Geels (2019) lists the following:

- economic competition between technologies
- business struggles between new entrants and incumbents
- political conflict and power struggles over agenda setting, problem framing, policies and regulations
- cultural and discursive struggles about framing of problems and solutions

Finally, the fourth phase completes the transition process with the institutionalization of the new technology.

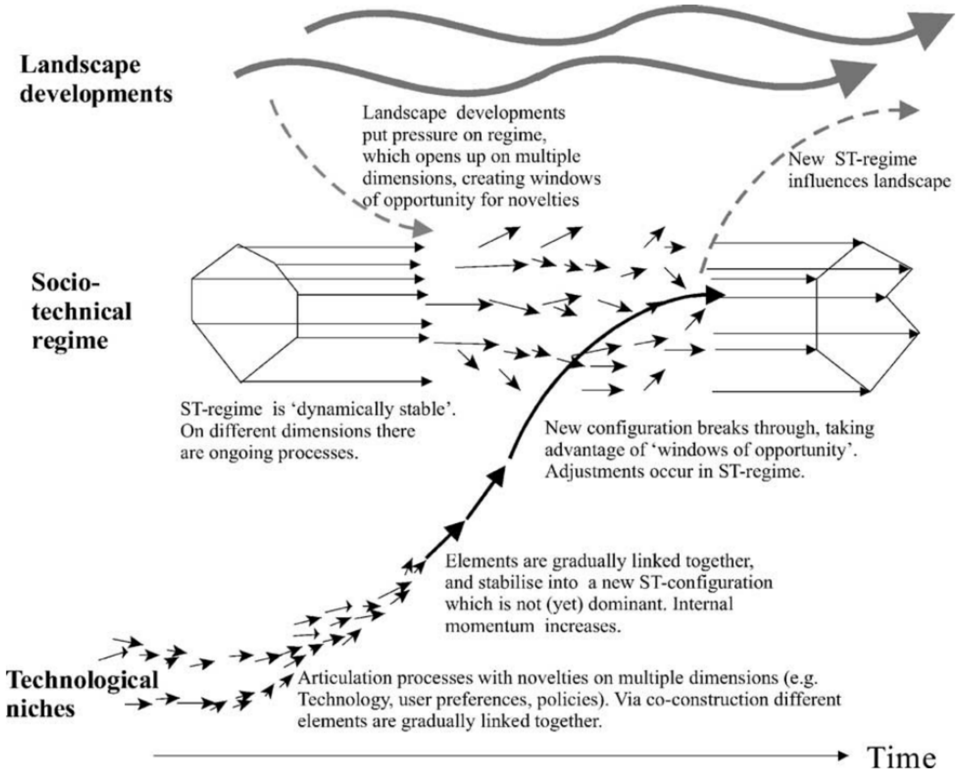

Figure 1: Early illustration of the MLP dynamics (Geels 2004a).

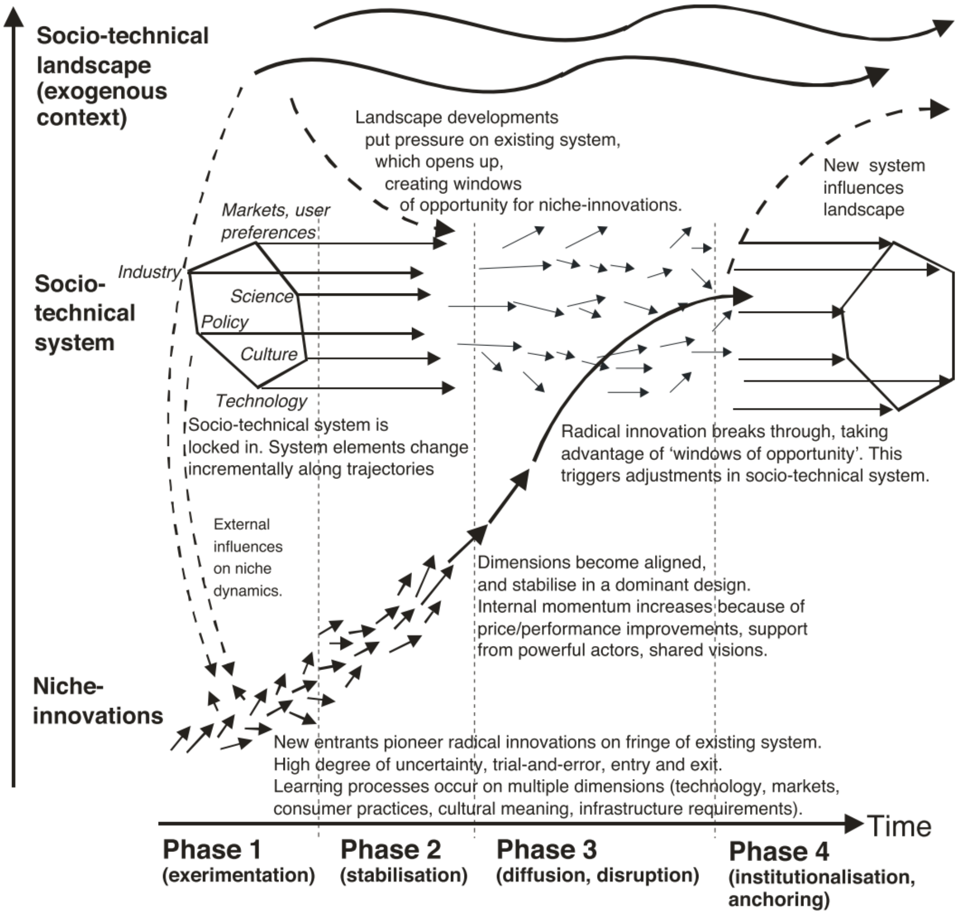

Figure 2: Later depiction of the MLP emphasizing the different phases of a transition. Here "socio-technical regime" is replaced by "socio-technical system" (Geels, 2019, p. 5).

Recognizing that transition processes can follow different pathways, Geels and Schot (2007) developed a "typology for transitions pathways" based on variations in the nature and timing of multi-level interactions. Here, they describe different options for how niche, regime and landscape level may interact and how this affects whether a transition will involve more or less disruption and radical change. They distinguish between the following four stylized pathways: P1 - Transformation path, P2 - De-alignment and re-alignment, P3 - Technological substitution and P4 - Reconfiguration pathway.

The transitions literature often conceptualizes the incumbents as the dominant actors within a regime. Geels (2014) explicitly speaks about "incumbent regime actors" and elaborates on their strategies to resist change. One such strategy is to influence politics (Geels, 2014, pp. 26-27), enabled by the proximity of regime actors to policy makers. The transition pathways outlined by Geels and Schot (2007) describe how transition dynamics on multiple levels will affect the strategies of "regime actors" and windows of opportunities for "niche actors". However, these typologies have been criticized for focusing too much on the landscape developments and factors that are externally given to the actors. Recent literature shows that incumbent actors choose different strategies when confronted with emerging transitions (van Mossel et al., 2018). An increasing number of studies find that some incumbent firms take a proactive role in the transition (Berggren et al., 2015; Steen & Weaver, 2017). Recent contributions from transitions geographers have questioned the widespread assumption that sustainability transitions always imply regime destabilization (van Welie, Cherunya, Truffer, & Murphy, 2018). Instead of generalizing the role of actors and transitions dynamics, transition geographers highlight the importance of conceptualizing spatial variety in regime structures and landscape forces (Coenen, Benneworth, & Truffer, 2012).

Drawing on organization theory, scholars have identified four main strategies that incumbents pursue to cope with ongoing changes in the socio-technical system during a transition. These are "first to enter niches", "follow into niches", "delay the transition" and "remain inert" (van Mossel et al., 2018). However, there is still a lack of knowledge about the strategies of niche actors in advancing transitions. Within strategic niche management in particular, the focus is mainly on experimentation, learning and creating networks (e.g. (Turnheim, Kivimaa, & Berkhout, 2018). Less attention has been devoted to how niche actors mobilize in order to change the regime. Some recent papers address the need for the phase out of existing technologies, so-called strategies of *'creative destruction'* (Kivimaa & Kern, 2016; Leipprand & Flachsland, 2018; Normann, 2019; Rogge & Johnstone, 2017).

However, the MLP framework illustrates that a transition is not only about removing specific technologies and replacing them with new and clean technology. The shift in socio-technical regime implies a change in deeply embedded structures and institutions. This comprises both the physical infrastructure and all three levels of institutions: regulative, normative and cultural-cognitive (Scott, 2008). In other words, an important aspect of the transition is to reconfigure the socio-technical system, to which I turn next.

2.2.3 Systems reconfiguration

Issues related to whole-system configuration have been identified as an important research agenda for the sustainability transitions community (Köhler et al., 2019). As one of the main conference topics of the IST 2018, the organizers underscored the importance of studying how system reconfiguration unfolds in different domains and how this relates to differences in specific areas like infrastructure and industry structures (IST, 2018). This implies studying the entire value chain associated with a technology within the socio-technical system as well as examining the architecture of the system, including how generation/production, distribution and consumption are linked. The calls for increased focus on whole system configuration are to a large degree the result of a bias within the sustainability transitions field toward studying new (and radical) innovations, thereby neglecting distribution and consumption components (McMeekin et al., 2019). This thesis addresses this gap with its assessment of grids configuration and system operation in papers 1 and 4.

When socio-technical systems move toward more sustainable configurations, this requires significant structural changes in existing systems (Geels et al., 2016). Even though Geels and Schot (2007) argue that the *reconfiguration pathway* (P4) is only one of several transition pathways, researchers acknowledge that all types of transitions inevitably entail a certain degree of reconfiguration within socio-technical systems. System reconfiguration will mainly take place on the regime level, and from the MLP regime definition (see above), it follows that there will be a change in the dominant structures, institutions, practices, rules and shared assumptions.

In their study of the long-term development of the European electricity system, Bolton et al. (2019) focus on infrastructure architecture and point to the importance of what they term "grand visions" for system configuration. Several scholars have pointed to the importance of visions for policy making (Foxon 2013; Foxon et al. 2013; Lilliestam and Hanger 2016). The visions represent normative aims for governance pathways and they are often implicit in the work and agendas of most actors involved in energy policy. Since normative issues about which energy future we want affect the policy positions of different actors and groups, visions are important for which pathways will be realized in the end. In Paper 1, we assess the policy positions of key actors and employ them as indicators for their preferred transition pathways.

Bolton et al. (2019) show how the entire electricity sector has been shaped through the ideas of key actors and institutions during critical phases of system building. The advancing energy transition induces change within several key components of the regime. Analyses of the future development of the electricity sector should therefore combine assessments of policy processes in conjunction with in-depth understanding of technical policies, "in particular, the nature, origins and evolution of the detailed technical rules, procedures and codes which enable such complex systems to operate" (Bolton et al., 2019, p. 66). This lends support to the claim of Verbong and Loorbach, who argued that "[T]he financial and regulatory aspects of existing energy regimes tend to be poorly understood, yet they play a major role in sustaining these, complicating the advancement of alternatives" (Verbong & Loorbach, 2012, p. 328). The last paper of this thesis (paper 4) picks up on the call for a better understanding of the technical rules within the electricity system, and how they interact with different market designs.

2.2.4 Niche and regime specifications

One criticism of the MLP has been that the framework does not provide sufficient specification of the regimes (Berkhout et al., 2004). In his response, Geels argued that the MLP leaves it open for the analyst to delineate the boundaries of analysis and operationalize the analytical levels from the MLP (Geels, 2011)[2].

For instance, the MLP provides no clear-cut definition of when a technology classifies as a niche technology and when it ceases to be a niche and eventually turns into a regime technology. This has important implications for when specific technologies are no longer entitled to protection and support measures for niche technologies should be phased out. Actors with vested interests might apply the

[2] "This criticism is about the normal problem of drawing boundaries and defining the topic of analysis. The MLP does not prescribe how broad or narrow the empirical topic should be delineated. The regime notion is an analytical concept that can be applied to empirical topics of different scope (primary fuels or entire electricity systems). The scope of the empirical topic will have implications for the operationalization of the regime concept (e.g. the number of actors, their relationships and the coordinating rules/institutions)" (Geels 2011)

argument of niches being ‘market mature’ as a justification for claiming ‘technology neutrality’ in the policy mix. I return to this in the discussion (see section 7.2).

In order to use and test theory, researchers must employ proxies (indicators), which serve as observable implications of the theories (Adcock & Collier, 2001, p. 532). Given that researchers will develop indicators according to their various research objects, theory should be as clear as possible about the different entities and concepts within the framework. Even though the MLP allows analysts great freedom to define their respective levels in the MLP, I wonder whether it would help scholars if the levels were more clearly defined. Then, analysts would still have some freedom when developing indicators for these levels, but there would be less doubt about whether something is actually niche, regime or landscape, or something in between. Given the importance of these different levels for describing transitions dynamics and pathways, clearer definitions would enable more precise description of what happens at different stages of transitions and which policies are better suited at these respective stages.

Geels and Schot (2007, p. 405) offer four proxies as indicators for when niche-innovations have stabilized and are “ready to break through more widely”. These are (1) learning processes have stabilized in a dominant design, (2) powerful actors have joined the support network, (3) price/performance have improved and there are strong expectations of further improvement (e.g. learning curves) and (4) the innovation is used in market niches, which cumulatively amount to more than 5% market share. The first three proxies stem from the literature on niche development, which emphasizes the following three main processes: learning, network building, and articulation of expectations.

Pertaining to the third proxy, innovation scholars have identified four different mechanisms that contribute to lower production costs as adoption of a technology increases: Economies of scale in production, learning by doing, incremental product development and economies of scope (Sandén & Azar, 2005). When the transition moves to phase 3, one can already observe the effects of an improved price-performance ratio of the technology.

The fourth proxy derives from diffusion research, which estimates that the diffusion curve may become self-sustaining and take off between 5 and 20% of cumulative adoption (Rogers, 1996). This builds on the concept of ‘critical mass’, defined as the point after which further diffusion becomes self-sustaining because enough individuals in a system have adopted the innovation (Rogers, 2003, p. 343). When the threshold for critical mass is reached, “further diffusion is self-generated by the innovation’s own social momentum” (Rogers, 2003, p. 360), thereby rendering the need for additional promotion superfluous. One important strategy for reaching a critical mass in a system is to provide incentives for early adoption. However, whereas diffusion theory argues that we need such incentives until the critical mass is reached, this thesis shows that it is difficult to define the thresholds within *sustainability* transitions. Often, various forms of state intervention are still needed even beyond certain thresholds. Hence, different types of policies should be evaluated to ensure sustainability targets are achieved within constrained time limits.

Diffusion scholars distinguish between three phases of a transition according to thresholds for market shares and diffusion rates (C. Wilson, 2012). The ‘formative phase’ is characterized by smaller-scale units and small increases in unit capacity. It is followed by the up-scaling phase, exhibiting large increases in unit capacities as well as numbers of units. The up-scaling phase corresponds largely to the diffusion phase within the MLP. Succeeding the expansion in the diffusion phase, the technology (or innovation) will enter into its final phase, i.e. a maturing, stable growth phase that eventually slows and saturates (Grubler, Wilson, & Nemet, 2016, p. 20).

Grubler et al. (2016) discuss various thresholds for market shares applied within the diffusion literature. Some scholars have suggested that the formative phase ends at 2.5%, whereas others argue that 1% is the threshold for when the technology 'takes-off' (see Grubler et al. (2016) for a discussion of thresholds). Drawing on Smil (2010), Sovacool (2016) applies a 25% market share threshold for his empirical evaluation of the duration of 10 energy transitions[3]. He finds that these 'rapid' energy transitions lasted only 1-16 years and concludes that "Clearly, this evidence suggests that some energy transitions can occur much more quickly than commonly believed" (Sovacool, 2016, p. 203). Disputing this lower threshold, Grubler et al. (2016) argue that grand transitions can occur when technologies reach 50% market share.

However, that a niche is ready to break through does not necessarily imply that it will *manage on its own* without any supporting measures in established markets and that it should be considered, per se, 'market mature'. This depends on various factors, both material and immaterial. The former includes existing infrastructure and lock-in of investments and assets. The latter includes policies, institutions and culture. This thesis investigates the needs of RE niche technologies in a period when they are about to reach – or have already reached – the stage where they are "ready to break through more widely". Many actors would argue that the RE technologies have already attained market maturity, which I show in the first three papers[4]. However, this thesis questions whether it is possible to apply such thresholds on *sustainability* transitions. Given that the sustainability dimension often involves a temporal aspect, state intervention and targeted regulatory policies might be needed in all phases of a transition to ensure sustainability targets are reached within a specific time frame.

Another challenge that derives from the inadequate definition – and distinction – between niche and regime relates to the role and classification of actors in the socio-technological system. Geels (2014) conceptualized niche- and regime actors as the newcomers versus the incumbents. However, recent studies have pointed to how incumbents engage with niche technologies. Considering the proactive role of incumbents and the many types of actors who cannot be classified either as newcomer or incumbent, we might need to consider other ways to conceptualize actors within the different levels. As a precondition for this, I suggest that sustainability transitions theory would benefit from making the definition of niches and regime levels in the different phases of a transition more explicit.

For empirical analysis of ongoing sustainability transitions, it is sometimes necessary to conceptualize shifts and boundaries. Even though analysts are free to demarcate their objective of analysis, it has not been common practice among transition scholars to conceptualize their MLP levels – or phases – up front. Moreover, the question of market maturity of niches is highly contentious and deserves more attention as transitions advance. Acknowledging that transitions undergo different phases, and that these phases might require different types of policies – which again involves different policy struggles, I argue that transitions theory would benefit from developing shared definitions or conceptualizations of the different levels and their boundaries. I will return to this in chapter 7.

2.3 The politics of transitions

Following the attempts to define transitions and its phases, the aspect of policy and politics deserves more attention. As the literature on sustainability transitions has rightly pointed out, transitions are inherently political (Avelino, Grin, Pel, & Jhagroe, 2016; Meadowcroft, 2009). This is, to a large extent,

[3] Smil (2010) defines energy transitions as the time that elapses between the introduction of a new fuel or prime mover and its rise to 25% market share (Sovacool, 2016, p. 203).
[4] In the public consultations to the European Commission about the Clean Energy Package, many industry actors and utilities expressed the view that renewables are market mature.

also true for past transitions. The literature on niche management describes how niche protection is a direct result of public policies (Smith & Raven, 2012).

The crucial role of politics and power has led to an increasing attention being given to this topic over the last ten years. Whereas research on the politics of transitions was identified as a research gap only few years ago (Markard et al., 2012), it has become “a widely acknowledged theme within sustainability transitions research” (Köhler et al., 2019, p. 6). Köhler et al. (2019) list a number of studies that have explored the issues of politics and power within transitions both theoretically and empirically. A common feature of these studies, however, is that they draw on or incorporate existing theories on politics and power from other disciplines, most importantly from political science, but also from sociology. There have, therefore, been few advancements of *new theory* from these endeavors. On the contrary, it is even tempting to ask a bit provocatively whether the increasing attention toward transition politics within the sustainability transitions community is something qualitatively new, or rather an incremental innovation stemming from the mere branding of policy studies of environmental issues as ‘sustainability transition literature’. At least, it should be acknowledged that political scientists, human geographers and sociologists have a long record of studying policy processes regarding environmental, climate and sustainability issues. It is true that these research communities have mainly treated the issues of technology and technological development as external entities and that their frameworks have not taken them into account as part of the study objects. At the same time, one should acknowledge that the various policy frameworks employed by transitions studies also often fail to incorporate the dynamic nature of technology within the limited scope of academic journals.

2.3.1 Transition studies and cross-fertilization with political science

The calls for a better understanding of the role of politics have led to an increasing attention toward studies of policy process theories among transitions scholars. Even though transition scholars have claimed that the politics agenda is now well explored (Köhler et al., 2019), Kern and Rogge (2018) maintain that transitions scholars have made limited use of policy process theories.

Kern and Rogge (2018) acknowledge the value of incorporating the insights from established theories on policy processes when making the *policy* and *politics* dimensions within sustainability transitions more sophisticated. They review five theories for studies of policy processes, which are selected due to their prominence in the field of policy studies[5] (Kern & Rogge, 2018, p. 103). These include the advocacy coalitions framework (ACF) (Sabatier & Jenkins-Smith, 1993), the multiple streams approach (Kingdon, 2014), punctuated equilibrium theory (Baumgartner & Jones, 1993), discourse coalitions (Hajer, 1995) and policy feedback theory (Pierson, 2000). Kern and Rogge provide a helpful discussion of how these theories can enrich transition theory and conclude that they are of great value for transitions studies, but also recognize some important shortcomings. One is that they are developed for analyzing individual policies, not policy mixes. Another is that their attention lies on explaining the outputs of policy processes (i.e. policies and legislation), and that they therefore largely neglect the study of policy outcomes (i.e. what the actual effect of adopted policies is). As a result, these frameworks should be further elaborated or extended in order to address important agenda-issues for sustainability transitions.

However, policy process theories are only one subfield within the political sciences. The rich tradition of institutionalism also offers important insights for understanding policy and politics within sustainability transitions. Notably, the MLP has its roots partly within institutionalism (Geels, 2004a). Moreover, some of the ‘policy process’ theories presented in Kern and Rogge (2018) have their origin

[5] Kern & Rogge (2018) note that the terms ‘public policy’ and ‘policy science’ are used interchangeably with ‘policy studies’.

within institutional theory. This is especially true for Pierson's notion of path dependence, which is a key concept within institutional theory, and for Hajer's work on discourse coalitions, which has been used to study institutions and institutionalization processes (Hajer, 1995).

Institutional theory is a broad and influential body of literature within the social sciences, most notably within political sciences and sociology. As a theory that seeks to explain the change and stability of institutions, it has provided sophisticated conceptualizations of different types of organizations on multiple levels, from national states and international regimes to firms and schools. It should also be noted that many of these contributions consider policy outcomes. Policy science scholarship within a wide range of topics, including employment, housing, education, tax systems and environmental issues, has employed policy regime perspectives which draw on institutional theory (Scharpf, 2000; Skjærseth, Eikeland, Gulbrandsen, & Jevnaker, 2016; C. A. Wilson, 2000).

This section takes a closer look at some of the main attempts to incorporate elements of policy theory into the transitions field. Since policy theory is an extremely broad and rich strand of literature, a complete literature review is beyond the scope of this thesis. Instead, I focus on the two theoretical frameworks that I draw on in my papers. Above all, I explore the cross-fertilization between transitions literature on the one hand, and institutionalism and ACF on the other. Institutionalism has been characterized as one of the most influential theories within the social sciences (Fuenfschilling & Truffer, 2014). It is, however, a broad body of literature comprising different branches including historical institutionalism, sociological institutionalism, rational choice institutionalism (Scharpf, 2000). The ACF is considered one of the key theories for explaining policy processes (Weible & Sabatier, 2018).

A literature search for the two combinations: 1) institutionalism and sustainability/energy transitions and 2) the ACF and sustainability/energy transitions yields a result of approximately 20 studies for each combination after cleaning the search result. The search reveals that the studies that combine the ACF with transitions are more frequently cited. However, it should be noted that the top-three on the list do not carry out a regular ACF study, which would include a detailed assessment of the members of the coalitions and their degree of coordination. Instead, these papers recognize the importance of advocacy coalitions for promoting new technologies. In what can be considered as one of the first studies to explicitly combine the transitions and the ACF perspective, Jacobsson and Lauber (2006, p. 259) note that:

> For a new technology to gain ground, *technology-specific coalitions* need to be formed and to engage in wider political debates in order to gain influence over institutions and secure institutional alignment. As part of this process, advocates of a specific technology need to build support among broader advocacy coalitions to advance the perception that a particular technology, e.g. solar cells or gas turbines, answers wider policy concerns.

The influential studies by (Negro, Hekkert, & Smits, 2007; Negro, Sum, & Hekkert, 2008) include advocacy coalitions in the technological system (TIS), and list them as one of the *system functions*. In their empirical assessment, they operationalize advocacy coalitions as interest groups with similar/merging preferences as stated in written documents.

As to the combination of institutional theory and transitions, there are several studies that do not explicitly mobilize so-called 'transitions theory' (in the sense of the MLP or TIS). Instead, they study the phenomena of transitions through the lenses of institutional theory (e.g. Leiren & Reimer, 2018).

The next sections will account for contributions in the literature that explore how insights from political science in general, and institutional theory and the advocacy coalition framework in particular, can enrich and complement transitions studies.

2.3.2 Institutionalism and MLP

A key focus of institutional scholarship is to explain the nature of different types of organizations as a result of different kinds of institutions. In his early work on the MLP, Geels outlines how this framework partly has its origins within institutionalism. The regime level is conceptualized as a "patchwork of regimes" (Geels, 2004a, p. 913). Geels consistently applies the term 'rules' instead of 'institutions' and argues that the regimes "exist of interrelated rules" (Geels, 2004a, p. 905). Geels and Schot (2007) note on page 403: "We talk about 'rules', because the term 'institutions' is often misinterpreted as public organisations". However, this implies a simplification of the institution concept, of which the formal rules are only one delimited part. Scott (2008) distinguishes between regulative, normative and cultural institutions, which corresponds to different forms of pressure.

Geels (2004a) distinguishes between technological, science, policy, socio-cultural and user and market regimes. Since there are interlinkages between the regimes, the socio-technical regime is conceptualized as the meta-coordination of the different regimes (see Figure 3). However, socio-technical regimes "do not encompass the entirety of other regimes, but only refer to those rules, which are aligned to each other" (Geels, 2004a, p. 905). The socio-technical regime concept is valuable for illustrating that the different aspects of the socio-technical system are interrelated. However, the distinguished regime types are not specified in further detail. It is also rather unclear how and to what extent the regimes are interrelated, and not least how this might be studied. In my opinion, transition scholars have barely engaged in these conceptual discussions.

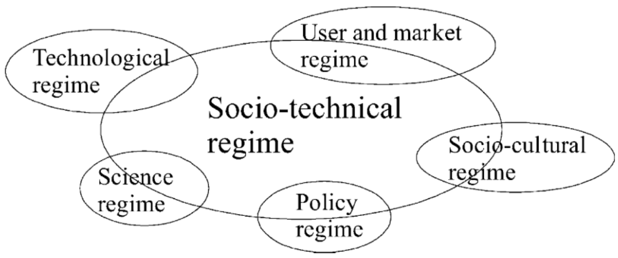

Figure 3: Interrelatedness of regimes (Geels 2004a)

Given the institutionalist legacy of the MLP, recent calls in the literature to enrich the MLP with different types of institutionalism (Andrews-Speed, 2016; Lockwood, Kuzemko, Mitchell, & Hoggett, 2017) might indicate that the institutionalist perspective has not been sufficiently elaborated in the transitions literature. Even Roberts and Geels (2019, p. 222) maintain that there is a need to enrich the MLP "with insights from historical institutionalism, with the aim of developing a more granular understanding".

However, in these authors' efforts to combine the MLP and historical institutionalism, it appears that the principle of meta-coordination has been abandoned. Where the earlier concepts of the socio-technical regime referred merely to the institutions that were aligned within each (sub)regime, they now perceive the policy regime as situated *within* the socio-technical regime: "We conceptualize policy regimes as embedded in broader sociotechnical regimes" (Roberts & Geels, 2019, p. 225). This would imply that the different regimes (market, policy, technology and so forth) are all embedded within, and are an inherent part of, the socio-technical regime. I agree with this conceptualization of the relation between regimes. In this thesis, I perceive the two main regimes that I study – the market regime and policy regime – as important parts of the socio-technical regime. Therefore, it is also important to keep the denomination, 'socio-technical regime' and not replace it with the entire 'socio-technical system', as is done by Geels (2019) (see Figure 2 in this thesis) and Markard, Suter, and Ingold (2016).

Regarding the overall objective of the MLP, i.e. to analyze how a socio-technical regime is transformed – including its organizations (i.e. actors), institutions (i.e. values, beliefs, norms, rules) and technologies – it seems evident that institutional theory can deliver fruitful insights especially about the first two entities; organizations and institutions. Explaining the stability and change of organizations and institutions is the overarching purpose of this theory. Institutional change has many parallels with regime change. They can be the result of social or policy learning, stem from the deliberate actions of individuals ("policy entrepreneurs") or coalitions, or arise from external pressure in the form of social movements or economic or natural crisis (Andrews-Speed, 2016, p. 220). Whereas Fuenfschilling and Truffer (2014) and Andrews-Speed (2016) explore the relevance of broader institutional theory for the MLP, other researchers have focused on historical institutionalism (Lockwood et al., 2017; Roberts & Geels, 2019) or organizational institutionalism (Wirth, 2014).

2.3.3 Advocacy Coalitions Framework and Transition Scholarship

The advocacy coalition framework (ACF) is a theory for studying policy change within a specific policy system, which provides detailed criteria for what characterizes political coalitions. Transition scholars have identified this framework as one of several policy theories that could harbor considerable potential for cross-fertilization of with transitions theory. The ACF has its origins in 1970s' USA and has been popular among political scientists who study environmental politics[6]. Also more recently, there have been numerous studies of environmental policy change which apply the ACF (e.g. Ingold, 2011; Kammermann & Dermont, 2018; Ydersbond, 2018). However, even though transitions studies and AFC are thought to have substantial potential for cross-fertilization, only Markard et al. (2016) have explicitly explored theoretical synergies with transitions literature so far. Although Hess (2014) mobilizes the MLP in his study of coalitions in renewable energy policy on the state level in the US, he does not engage with the ACF.

The purpose of the ACF is to explain major policy change. The underlying assumption is that actors who share similar beliefs work together in a coalition through which they influence the policy process. Changes in coalitions (and the underlying beliefs) are regarded as a key explanation for major policy change. The ACF defines coalitions as persons or groups that meet the following two criteria: 1) engaging in non-trivial degree of coordination and cooperation and 2) sharing "policy core beliefs" (Jenkins-Smith et al., 2014, p. 195). Coalition members regularly seek to influence public policy in a specific policy subsystem.

In the first three papers of this thesis, I study the policy subsystem "European electricity policy". I perceive this subsystem as a distinguished part of the socio-technical system. The first two papers assess the effects of legal policies on specific aspects of the socio-technical system (renewable energy and system reconfiguration). As shown in the third paper, the subsystem comprises actors both on the regime and niche levels.

Sabatier (1998, p. 103) characterizes "policy core beliefs" as the fundamental normative commitments, causal perceptions and value priorities across entire policy domains. Policy core beliefs are stable over time and more resistant to change than what is demarcated as the *secondary aspects* of the belief system. Secondary aspects constitute the lowest level of the belief system. They represent what can be described as the actors' policy preferences with respect to concrete policy options, e.g. specific policy design, policy instruments, budgetary allocations etc.. These preferences are more prone to

[6] Jenkins-Smith et al (2014) count 128 studies applying the ACF on environmental politics between 1987 and 2013.

change based on new knowledge and experience. Throughout the thesis, I use the term *policy preferences*.

In addition to shared policy core beliefs, the ACF assumes that members of a coalition "engage in a non-trivial degree of co-ordinated activity over time" (Sabatier, 1998, p. 103). This aspect of the ACF recognizes that many actors could share the same policy core beliefs but still not act together in pursuit of common policy objectives. In order to constitute a coalition that contributes to policy change, there has to be some degree of joint activity or coordination.

Interesting for transitions researchers who study 'socio-technical regime shifts' is the conceptualization of policy change. The Advocacy Coalition Framework perceives policy change as a result of four mechanisms occurring either individually or in concurrence: 1) *external shocks* that change the conditions stakeholders operate within, 2) internal shocks from political failures within policy subsystems, 3) policy-oriented learning by which coalition members gradually change their perceptions, and 4) negotiated agreements between previously conflicting coalitions (Jenkins-Smith et al., 2014, p. 201-2013). Since policy change necessarily involves a shift in coalitions' structures, assessments that demonstrate how coalitions form and change can provide important information about ongoing change in policy systems. This is done in paper 3.

2.4 Transition policies

Against a backdrop of urgent environmental challenges, rapid sustainability transitions are needed more than ever. Since sustainability transitions are defined as transformative changes in socio-technical systems toward more sustainable modes of production and consumption, it is clear that these are comprehensive processes which involve different types of actors and institutions. Hence, transitions have several objectives, which is why different policies are needed to promote them. Policy mixes for sustainability transitions should consider these different objectives and how to reconcile them in a consistent and coherent policy framework.

This section discusses and systematizes different policy approaches for promoting a transition. It assesses insights on policy approaches from different disciplines: economics, innovation studies and policy science. Given the role of technological change, innovation and innovation policy might be essential for a transition. At the same time, the sustainability objectives of a transition imply that policies for pollution control also have an important role to play.

2.4.1 Innovation policy and sustainability

Innovation policy is a relatively new term that has become increasingly popular over the last two decades. Fagerberg (2017, p. 497) argues that a broad definition would be "all policies that have an impact on innovation", whereas a narrow understanding is policies "created with the intent to affect innovation". Several policies that we today call innovation policy were initiated under different labels, including industrial policy, research policy or technology policy. With respect to the initial definitions of the term innovation – which includes not only new products, technology, ways of producing and consuming, but the process of bringing these ideas into practice – it is clear that innovation policy also involves different types of instruments and strategies. In the post-war period, the most dominant way to think about innovation policy was the so-called 'linear model' (Kline & Rosenberg, 1986). It rests on the presupposition that scientific progress is the main driver for innovation. In this perspective, key innovation policies entail support for scientific activities in firms and universities, also called research and development (R&D).

Striving toward increasing levels of sustainability, sustainability transitions pursue several objectives. Two of the main objectives are pollution control and technological change. The first objective relates to environmental considerations and the need for limiting pollution or resource exploitation in order to stay within planetary boundaries (Rockström et al., 2009). This has typically been the domain of public policy and economics. The second objective addresses the need to develop new technologies, which is a key focus within innovation studies. During the past decade, it has become increasingly clear that combining these two will also involve new ways of organizing society. This is now explored within transitions studies, but also within the social sciences as such.

Innovation scholars distinguish between environmental policy and innovation policy, but acknowledge that they are interrelated. Kemp (2011, p. 6) argues that the market for eco-innovations is "largely a market commanded by environmental policy" and that the two should work in tandem. In this perspective, we need environmental policies to set policy targets for objectives such as emissions reduction and nature protection, and we need innovation policies to stimulate the development and diffusion of clean technologies and socio-technological systems.

In the light of combined objectives, I suggest the term "transition policies" as an umbrella term for policies that enable, promote and accelerate transitions. This means that policy mixes for sustainability transitions ideally should contain policies that combine both objectives, either by combining different policy instruments with distinct (but consistent) objectives, or through policy instruments that do both.

Schot and Steinmueller (2018b) have argued that the linear model is the first of "the two established frames" of science, technology and innovation policy. The second frame is the literature on innovation-systems, which emerged at the end of the 1970s. Scholars began to assess the role of specific (national) institutional frameworks for enabling innovation, and policy makers became more concerned about how (and if) policy can contribute to raising innovation activity (Edler & Fagerberg, 2017).

The "national innovation system" approach (Lundvall, 2007) is a key framework within the literature on innovation systems. It is characterized by increasing attention toward how various factors within an innovation system interact, and how societies could exploit the benefits of innovation processes for economic growth. This scholarship prepared the grounds for the framework called "technical innovation systems" (TIS) (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Negro et al., 2007), which is considered a key theoretical approach within sustainability transitions theory as well.

Due to increasing societal challenges and problems, which can be derived from our moral obligation to achieve the Sustainable Development Goals, Schot and Steinmueller (2018b) argue that we need a third framing focusing on transformative change. The third framing draws on insights from the literature on sustainability transitions. However, they advocate that the third framing should not only be considered as "a nice addition" to the first two framings, but "necessitates a rethinking of it" (Schot & Steinmueller, 2018a, p. 1583).

Distinguishing environmental policies from innovation policy, and the question of whether they should merge or coexist in a policy mix for sustainability, is largely a theoretical debate. How important insights from the literature on innovation policy can cross-fertilize the growing literature on how to solve critical environmental and societal challenges has been – and still is – a key issue for the sustainability transitions literature, which will be discussed in the following sections.

2.4.2 Policy mixes for sustainability transitions

In the search of guidance for how to promote and accelerate transitions, researchers have suggested studying policy mixes for sustainability transitions (Del Río, 2014; Kivimaa & Kern, 2016; Rogge et al., 2017; Rogge & Reichardt, 2016). This literature highlights the need to analyze the interplay of policies and how the introduction of several policies might lead to synergy or negative effects. An effective policy mix must ensure consistency and coherence both between targets and measures, but also between the various measures in the mix. There are different conceptualizations of policy mixes; see Kern, Rogge, and Howlett (2019) for a thorough discussion and literature review. An important contribution from recent studies is that policy mixes for sustainability transitions should also take phase-out policies into account (so-called creative destruction in Schumpeter's term), due to lock-in of existing and polluting technologies (Kivimaa & Kern, 2016; Normann, 2019).

Interestingly, the "policy mix for sustainability transitions" literature is to a large extent applied in case studies where the niches are well beyond their formative phase (and would no longer qualify as niches within diffusion literature). Many of them are rather advanced in their upscaling phases, while they still need political measures to ensure continued development. Indeed, when considering thresholds for market share, one should also take the context into account. Should thresholds for market share relate to national, regional or global market shares?

The example of electrical vehicles (EVs) is illustrative for the role of policies in sustainability transitions. Despite increasing market shares both globally and for the lead market, the IEA highlights the need for policies for further deployment:

> Policies play a critical role. Leading countries in electric mobility use a variety of measures such as fuel economy standards coupled with incentives for zero- and low-emissions vehicles, economic instruments that help bridge the cost gap between electric and conventional vehicles and support for the deployment of charging infrastructure. (IEA 2019, p. 4).

Table 3: EV stocks and market shares of new sales, global and Norway (IEA, 2019b; The Norwegian EV Association, 2019)

EVs in measures	Global market	National lead market (Norway)
Total stock	2018: 5.1bn 2017: 3.1bn	2018: 296k 2017: 209k
Share of total stock	n.a.	10.7%
Growth rate of stock (2018 on 2017)	68%	42%
Market share of new car sales (2018)	3% (IEA 2019, figure 1.2)	46% (IEA 2019)[7]
Growth rate of new sales (2018 on 2017)	68% (IEA 2019 p. 35)	26%[8] (Elbilforeningen)

Table 3 shows the state of EVs globally and in Norway, the world's leading national market, as of 2018. Even in Norway, where cumulative market shares are well beyond the 5% threshold suggested for the MLP (Geels & Schot, 2007), the government continues to support EV deployment with a variety of measures, including tax exemptions and reduced parking fees and road user charges. The main rationale of these measures for early adoption and technology development (see policy approach C in section 2.4.3) is to reduce national emissions. Despite high market shares, the EV niche still needs considerable support to drive both global and regional transition dynamics.

The sustained need for policies when technologies move beyond market thresholds might question the applicability of niche definitions and proxies from diffusion theory. Indeed, most transitions scholars implicitly use the term 'niche' for many new technologies and user practices that are beyond the specified thresholds. This implies that it probably makes sense to distinguish between thresholds and niche/regime classifications, and to decide whether state intervention is still needed, as noted in section 2.2.4.

[7] The Norwegian EV Association and IEA operate with slightly different numbers for market shares of new sales. The Norwegian EV Association's account for new sales are 31% for EVs and 17% for PHEVs in 2018 (=48%)

[8] Own calculation, based on figures for new sales in 2017 (38%) and 2018 (48%).

2.4.3 Typology of transition policy approaches

Policy instruments can be organized into overall groups of policy approaches, according to their main organizing principles. Table 4 lists the different types of policy approaches, their main principles and policy instruments.

When it comes to environmental policies, economists and political scientists typically distinguish between command-and-control instruments (Policy Approach A) and market-based incentives (Policy Approach B) (Perman, Ma, McGilvray, & Common, 2003; Stavins & Whitehead, 1992)[9]. Command-and-control involves prescriptions, prohibitions and standards like technology or performance-based standards. Market-based incentives comprise two main instrument types: pollution charges and tradeable permit systems.

Innovation scholars have distinguished the policy approach for technology development and early adoption (Kemp et al., 1998). Finally, some transition scholars have viewed the experimentation and networking activities as additional to the technology development approach (Geels, 2019). Policy approaches C and D are mainly derived from the innovation and transition literature. I could have added a distinct policy approach for destabilization. However, destabilization can also be achieved through policy approach A, B or C, which is why I have chosen not to categorize destabilization as a distinct policy approach or principle.

Transition scholars have pointed to the need for technology-specific policy instruments in the first two phases of a transition (Jacobsson & Lauber, 2006; Kemp et al., 1998; Sandén & Azar, 2005). They have highlighted the advantages of niche protection and nurturing when it comes to policy mixes for new and radical technologies. The main reason is that policy instruments that give priority to cost-efficiency are not powerful enough to spur technology development (Azar & Sandén, 2011).

Neo-classical economists normally favor market-based policies, and tradeable pollution permits in particular. Arguably, such policies will ensure a higher degree of cost-efficiency, defined as more emissions reduction at a lower cost (Goulder, 2013). Moreover, economists have argued that RE subsidies have no effect on emission levels as long as the sector is covered by a cap-and-trade scheme (Jarke & Perino, 2017). Paper 2 engages with this discussion about the preferred policy instruments for the energy transition. It shows how policy preferences are strongly correlated with types of actors and business models.

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[9] Economists also add an institutionalist approach to pollution control, where the acceptable pollution level is achieved through bargaining. Since efficient bargaining outcomes are hard to obtain, this approach is not included here.

Table 4: Different types of transition policy approaches (Azar & Sandén, 2011; Boasson & Wettestad, 2013; Geels, 2019; Perman et al., 2003; Rogers, 2003; Stavins & Whitehead, 1992)

Types of policy approaches for sustainability transitions

	Policy Approach A	**Policy Approach B**	**Policy Approach C**	**Policy Approach D**
	Command-and-control	**Market-based**	**Technology development/ early adoption**	**Network governance**
Main principles	Government forces all actors to behave in the same way, regardless of their relative costs.	'Internalize externalities' or 'Polluter-pays-principle' Financial incentives (or disincentives) on pollution-related activities that make it in the self-interest of actors to behave in desirable ways.	Special incentives for early adopters of new clean innovations. Help establish niche markets that reduce barriers and enable cost reductions and improved performance	Facilitate learning processes, networking and experimentation
Policy instruments	Prohibition Prescription Technology standards Product standards Emission performance standards (EPS)	Tradeable pollution permits Pollution charges: - Taxes - Fees, levies	R&D Feed-in tariffs Green certificates Demonstration projects Market advantages Specific benefits	Demonstration projects Concessions for sites for experimentation Grants Loans
Pros	Enables high degree of control	Provides incentives to develop and adopt new improved control technologies	Helps establish new industry	Supports interdisciplinary collaboration and participation of citizens
Cons	Can be very costly for firms to comply with. Little financial incentive to perform better than the standard	Favors incremental over radical innovation	Costly for public budgets	Can be resource demanding. Might depend on sufficient engagement of the public

More recently, economists have also recognized the need to subsidize green technologies. Economic assessments find that optimal environmental regulation should use both an input tax (carbon tax) to control current emissions and research subsidies for promoting clean technologies (Acemoglu, Aghion, Bursztyn, & Hemous, 2012). The findings show that it is not optimal to use a carbon tax to reduce emissions and encourage clean technology development (Acemoglu et al., 2012, p. 133). Instead, the ideal combination consists of a mix of policy approach B and C. It should be noted that these economic assessments only investigated the relationship between R&D subsidies and a carbon tax, and did not look at production support (e.g. feed-in tariffs). This is most relevant in phase 1 and 2 of a transition. When the transition advances and clean technologies become increasingly competitive, the need for R&D decreases and other types of policies become more important.

In chapter 6, I will continue the discussion on the role of different types of policies in the third phase of a sustainability transition. This will be assessed in the light of the findings of the individual papers in the thesis.

4 Methodology

The thesis applies both qualitative and quantitative techniques to explore the relationship between markets, policies and system configuration within energy and climate policy. As elaborated in the introduction, the papers explore various aspects of this relationship. A main contribution of the work is to combine different types of methods that enables a more detailed understanding of the non-governmental actors within EU policy subsystem than earlier studies have done (e.g. Szarka, 2010; Ydersbond, 2018).

Before I continue to present the research design, I would like to position this thesis with respect to theory testing versus theory development. The sustainability transitions literature is a highly interdisciplinary field where researchers employ all types of social science methods. The main theories – or frameworks – within transitions studies (MLP and TIS) do not provide researchers with explanatory mechanisms or propositions that are suitable for theory testing. Consequently, when researchers want to use theories for *causal explanation*, these mostly stem from other social science disciplines, including sociology, anthropology, geography, political science, economics and management. This does not discredit transitions theory. Rather, it contributes to enhanced sensitivity toward what the frameworks are and what they can do. For example, the MLP is most often used as an overarching framework within which the specific phenomena of a transition unfold.

The empirical work of this thesis finds itself at the intersection of 'using' transitions theory and the need to apply other theories to explain the findings. Indeed, the nascent transitions scholarship allows great freedom to investigate new territory and explore the field through new conceptual developments and new data, thereby "grounding the theory" (Corbin & Strauss, 2015, p. 77).

The broad use of different methods and theories in the thesis reflects the overall objective of the thesis, i.e. exploring main barriers and drivers for the energy transition and the relationship between market and policies. This quest is by nature explorative. It is guided by theory in the sense that it rests on a huge literature from various disciplines about the technical and political challenges and social controversies at hand. Nevertheless, this sustainability transition is something new which has not yet been accomplished anywhere in the world. Moreover, the current phase of the transition is also new ground for transitions scholars. We lack good concepts and analytical models for the dynamics of the third phase of a sustainability transition, in which niche and regime levels become increasingly entangled. Therefore, the main focus on the thesis is on developing and recombining concepts which can enhance our understanding of theory. This would not have been possible through mere testing of hypotheses and relying solely on propositions derived from theory.

4.1 Research design

The overarching objective of the thesis has been to explore the main controversies within the European energy transitions. This overall transition is an area of tremendous development (see chapter 5) and is therefore of particular interest to transitions scholars. I am interested in the main drivers and barriers for the transition in the electricity sector and in the relation between market driven and regulatory driven climate policies. Of itself, the European energy transition is too big and complex for a single doctoral thesis. The four papers are examples of demarcated case studies (Yin, 2014), which vary in scope and level of analysis.

George and Bennett (2005, p. 5) define case studies as "the detailed examination of an aspect of a historical episode to develop or test historical explanations that may be generalizable to other events". The papers are examples of case studies that primarily seek to develop generalizable explanations of the ongoing European energy transition. The first three papers apply a mixed-methods approach, combining development of concepts and quantitative assessments.

A strong feature of the work is the establishment of concepts and identification of main lines of distinctions within sustainability transitions pathways, policy mixes, advocacy coalitions and electricity market designs. Together, the papers help explain the inherent characteristics of the transition and contribute to enriching our understanding of transition dynamics.

The use of concepts is a key characteristic of qualitative research. This involves establishing, defining and applying various concepts (Goertz & Mahoney, 2012, p. 128). Scholars have argued that this is a precondition for qualitative as well as quantitative research. We need to understand "'what is?' before asking 'how much?'" (Collier & Gerring, 2009, p. 4). Within some qualitative research traditions, the development of concepts and categories are considered as *theory development*:

> What do we mean by *theory*? For us, theory denotes a set of well-developed categories (themes, concepts) that are systematically developed in terms of their properties and dimensions and interrelated through statements of relationship to form a theoretical framework that explains something about a phenomenon (Hage, 1972 in Corbin and Strauss (2015, p. 62)).

Various sociological and political science traditions like Grounded Theory and case study research highlight the need for typologies and categories (George & Bennett, 2005). This is a type of theory development that occurs through systematically working with and organizing data, and by means of abstracting basic-level concepts to higher-level concepts. Concepts of varying levels of abstraction help reduce the amount of data because phenomena with common characteristics are grouped under the same conceptual heading (Corbin & Strauss, 2015, pp. 76-77). Higher-level concepts allow for greater levels of abstraction, thereby gaining explanatory power. For theory development, the objective is to develop concepts specific enough to capture the substance of the phenomenon and yet general enough to serve as a part of a theoretical argument (Goertz, 2006). Figure 4 shows the relationship and level of abstraction in the form of a pyramid.

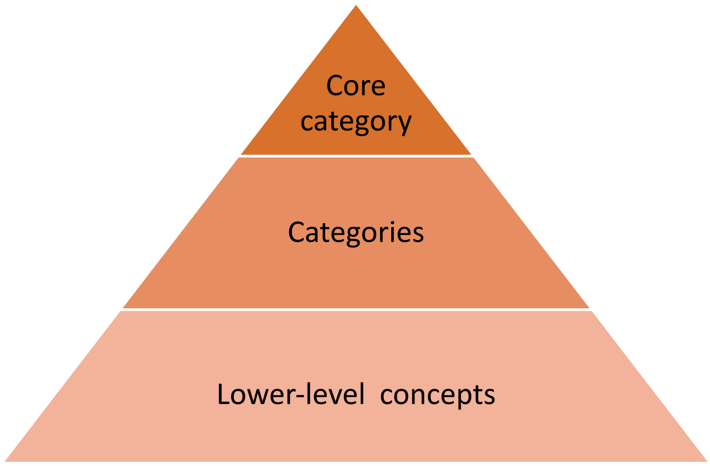

Figure 4: Pyramid showing the relationship between different types of concepts (Corbin & Strauss, 2015, p. 77)

Inductive analysis means starting from the bottom of the pyramid with the lower-level concepts and developing 'higher' core categories based on these lower-level concepts. Above all this was done in paper 4, where I had few theoretical propositions for the study object. Deductive approaches set out with expectations about higher level categories from the literature. This was done in papers 1-3, especially for the core categories of centralization and decentralization (Funcke & Bauknecht, 2016), and for advocacy policy beliefs (Sabatier, 1998). However, for the analysis and coding scheme it was necessary to establish categories and lower-level concepts strongly grounded in data.

This thesis does not apply Grounded Theory, but is inspired by some of its techniques for how to build new theory. Whereas Grounded Theory scholars claim that theory should be entirely data driven and reject starting from theory, they also acknowledge that "theory remains relevant as a foundation for explaining phenomena and for providing concepts and hypotheses for subsequent research" (Corbin & Strauss, 2015, p. 62). Less dogmatic qualitative scholars recognize that most procedures applied in qualitative analysis require some degree of analytic induction, but that "in all these cases, however, inductive and deductive analyses are mixed" (Huberman & Miles, 1994, p. 431).

The task of organizing different categories and relating them through comparison or contrast has been formalized into Typology theory (George & Bennett, 2005, p. 235). This form of practicing social science research is a tradition that stems from Max Weber's discussion of "ideal types" in the early 20th century (Lepsius & Wendt, 2017). Advantages of this way of performing social science research include the ability to address complex phenomena without oversimplifying and clarifying similarities and differences among cases to facilitate comparisons (George & Bennett, 2005) p. 233. Typological theory is defined as

> a theory that specifies independent variables, delineates them into the categories for which the research will measure the cases and their outcomes, and provides not only hypotheses on how these variables operate individually, but also contingent generalizations on how and under what conditions they behave in specified conjunctions or configurations to produce effects on specified dependent variables (George & Bennett, 2005, p. 235).

The specified conjunctions or configurations of the variables are called "types". Importantly, typological theories differ from historical explanations in that they specify generalized events that might occur independent of a specific sequencing order.

4.2 Overview of methods in the papers

The main methods used throughout the thesis are qualitative methods, but with considerable quantitative elements. Paper 3 represents an exception in that it applies two quantitative methods: a multi-criteria cluster analysis and a network analysis. For all papers, documentary analysis and interviews are the key methods that I have employed. The qualitative software nvivo was used for the coding of policy preferences and policy core beliefs. Table 6 provides an overview of theory, methods and data in all four papers.

The first three papers applies a form of mixed-methods approach in that they translate qualitative findings (concepts, preferences) into numerical values. For this exercise, I have used Excel to calculate and weight the overall values for both policy preferences (paper 1 and 2) and policies (paper 1). In paper 3, the software R is used to assess the clusters of actors and to illustrate their reported cooperation. The cluster analysis for paper 3 was carried out by my co-author, Lorenz Kammermann (University of Bern), on the basis of the data I provided. Joar Kvamsås (University of Oslo) produced the figure of the network showing collaboration between actors identified through the survey. The detailed procedures for each paper are specified in the methods sections of these papers.

Table 5: Overview of theory, methods and data in the papers

	Theory	*Case / Object of analysis*	*Methods*	*Data sources*
Paper 1	Sustainability transitions theory Theory on 'Policy mixes'	EU's electricity policy mix The policy process for the Clean Energy Package Key stakeholders' policy preferences for the energy transition The dichotomy centralization vs decentralization in three main components of the electricity system: production, grids, system operation	Assessment of policy preferences through document analysis Policy mix analysis: Assessment of legal documents based on scientific literature, interviews and background talks Visual illustration of preferences and policies through coding, showing the directionality of policy mix Semi-structured interviews to elaborate on and confirm our findings	Consultation responses to the EU Commission: - NEM - RED Policy mix analysis: Implemented EU policies (EU directives and regulations) Coding of policy values (qualitative assessment) showing the directionality of policy mix 7 Interviews Background talks Observations
Paper 2	Theory on 'Policy mixes' Institutional theory	EU's policy mix for decarbonization The policy process for the Clean Energy Package The policy process for the EU ETS reform The relationship between key policy instruments in the policy mix: EU ETS vs RE Directive.	Assessment of policy preferences through document analysis Visual illustration of preferences Semi-structured interviews to explain strategies of key actors	Consultation responses to the EU commission: - ETS reform 2013 - ETS reform 2014 - ETS reform 2015 - 2030 Energy and Climate Framework - NEM - RED 7 Interviews
Paper 3	Sustainability transitions theory Advocacy Coalition Framework	The policy process for the Clean Energy Package Advocacy coalitions of key actors	Assessment of policy core beliefs through document analysis Assessment of non-trivial collaboration through a survey Identification of advocacy coalitions through cluster analysis, network analysis and PCA Assessment of temporal development through literature review	Consultation responses to the EU commission: - NEM - RED Where there was not sufficient data quality, other documents were considered. Survey sent to key stakeholders
Paper 4	Sustainability transitions theory (MLP); whole-system perspective Institutional theory	Wholesale electricity market design in Germany and the Nordic electricity market. Assesses implications of different market models for the energy transition.	Establishes framework for assessing compatibility of market design and transition Comparative case study Thorough literature review of techno-economic scientific literature and 'grey literature' Semi-structured interviews + Background talks Assessment of consultation responses	26 interviews and background talks Data on system costs, electricity network plans, hedging volumes. Scientific techno-economic literature on the topic. Consultancy reports Government documents EU documents (ACER, ENTSO-E) Consultations: - Monopolkommission - German Government

All papers applied the analytical strategy of “playing with data” in the initial stages of the research process (Yin 2014, p. 135). This was a crucial feature of the creation of the coding scheme. This involves making a matrix of categories and placing the evidence within such categories. This research step has been predominantly data driven and is in this respect inspired by principles in the sociological tradition of Grounded Theory (Corbin & Strauss, 2015). A key task has been to establish and develop concepts and categories from the data to enable higher theoretical abstraction. This is especially the case for paper 1 and 4. Even though all papers rely on theoretical propositions to some extent and started out with some expectations from the literature, this was the dominant approach in paper 2 and 3, which began with some expectations from the literature about the policy preferences and policy core beliefs of specific groups of actors. As such, these two papers are mainly theory driven, but they combine deductive and inductive principles since key categories and rankings are strongly grounded in data. Moreover, a main achievement of these two papers was to develop the categories and rankings that produced the largest degree of distinction between the various types of actors and coalitions.

The methods applied combine explorative and inductive elements with theoretical propositions from different strands of literature. Above all, the empirical work involves the development of typologies and typology theory (George & Bennett, 2005), core categories and basic-level concepts that are largely grounded in data (Corbin & Strauss, 2015). The thorough, systematic and ‘grounded’ assessment of large data material is combined with deductive procedures in which I refer to established theories like the Advocacy Coalition Framework and institutionalism. Given that studies of market design necessarily involve a rich and comprehensive assessment of the techno-economic literature on the topic, some of the middle or lower level concepts for the typology categories draw on findings and discussions within economics and electricity market modeling. The overall categories for the market typology were inducted from the comprehensive assessment of data.

The level of analysis within the papers varies. The first two papers focus on the policy preferences of non-governmental actors and stakeholders within EU policy. The third paper applies ACF theory and identifies advocacy coalitions, using largely the same data and sample as paper 1. Finally, paper 4 takes a different analytical approach and identifies the main characteristics of market designs, which is here operationalized as *part of the energy policy subsystem*. Instead of focusing on the preferences of actors, I focus on the main properties – i.e. strategies, ideas and institutional logics – that underlie the respective market designs. Even though I have collected ample data about policy preferences for different groups of actors for the fourth paper as well, this is not the paper’s main focus. The scope of the paper did not allow for including a comprehensive and structured assessment of these preferences.

Paper 1 (Actors, policies and transition pathways) develops the typology “centralization versus decentralization”, which describes both a feature of the configuration of the electricity system and a property for specific technologies. Subsequently, it assesses the preferences of actors and implemented EU policies according to these typologies. It is important to note that the core categories, ‘centralized’ and ‘decentralized’ are not fully mutually exclusive. However, on the lower-concept level, policy preferences and policy design elements were coded according to a ranking procedure which used a Likert scale (1-4). It was only possible to choose one value for each statement on each sub-coding dimensions. Eventually, the results for each sub-dimension were added up in order to achieve one value for each core category. This practice is largely inspired by methods applied within the Advocacy Coalition Framework, where coding procedures for agreement or disagreements of actors with concepts are used to identify networks and advocacy coalitions (Ingold, 2011; Leifeld, 2013). However, paper 1 applies the coding also on the policies within the mix and compares it with the preferences of actors. This pairs well with the overarching objective of the paper, i.e. to explore preferences for different sustainability transitions pathways within the European energy transition.

Paper 2 (The EU ETS and RE policies) builds on rational choice institutionalism, predicting that the preferences of actors will be stable over the time and consistent during policy processes. This paper derives its expectations from existing literature on the topic. However, the specific coding categories and the ranking values of the respective categories stemmed from a predominantly inductive process. In line with the propositions of Grounded Theory (Corbin & Strauss, 2015), I explored the data material to identify the key concepts and main distinctions between the different types of actors.

Paper 3 (EU energy policy coalitions) is the paper which draws the most on existing theoretical frameworks of all papers in the thesis. The paper uses established methods and theory from the Advocacy Coalition Framework to identify main coalitions within EU energy policy. However, it still applies inductive principles for identifying the main dimensions – and the ranking on these dimensions – that distinguish actors and coalitions. The link to transitions studies is that the energy and climate 'policy subsystem' is currently in – or moving into – an advanced stage of the energy transition. Here, the transition is not the research object as such, but the setting within which we can observe the changes in advocacy coalitions. Methodologically, I argue that ACF methods are useful to throw light on "the politics of transitions".

Paper 4 (The Power of Power Markets) compares different variants of a liberalized electricity market and develops a typology for zonal market designs. Even though the types represent contrasts, they are not necessarily negations of each other. Therefore, a coding of these types as contrasts is not appropriate. Instead, this use of concepts and typologies adheres to the qualitative tradition, where researchers often allow categories to partially overlap with one another (Goertz & Mahoney, 2012, p. 171). Here the 'typology' represents the cases and the categories according to which the distinct 'types' should be assessed. Interestingly, a social science study of market models derived in an iterative process of inductive and deductive elements identifies other elements than a merely techno-economic study would do. These elements include the overall strategies, dominant ideas and the institutional logics within the different market designs. This study is an example of Typology Theory in that it not only develops the categories, but provides satisfying theoretical explanations for the correlations (George & Bennett, 2005, p. 239). Further, the paper discerns a set of dimensions that are key for the success of the energy transition. Given that actors strongly disagree on the importance of these respective dimensions, social science research is important to understand the controversies around these dimensions. The level of contestation and influence of different types of actors on the two market designs are not documented in the techno-economic literature. Moreover, this is a research domain which is not yet well explored by transitions scholars.

4.3 Data

The data for this thesis consists of a broad array of material and includes qualitative and quantitative data. The most important sources are a large sample of consultation responses to the European Commission for 3 different policy processes and 34 interviews. For the policy mix assessment in paper 1, the policy documents are the main source, accompanied by extensive consultation of other types of data to assist the evaluation of each policy design element. Further, I have used different types of public documents, statistics, company annual reports, media articles (Euractiv, montelnews), a vast array of grey literature and reports. I have also attended several events. The various types of literary sources are listed in the Table 6.

4.3.1 Qualitative data

Qualitative data represents the main body of data for the thesis. Below, I list the various types of literary sources applied through the thesis.

Table 6: Overview of literary sources of data in the thesis

Literary sources
Publicly available consultations responses to the Commission for the following topics: - RE directive - Electricity Market Directive - ETS reform
Publicly available consultation responses to the German Government: - Strommarkt 2.0 green paper - Electricity grid regulation (StromNZV) Publicly available consultation responses to the German Monopolkommission: - Special report on energy market 2018
EU legal documents: - EU directives - EU regulations - EU guidelines - EU network codes
European Commission: - White/green papers - Drafts legal documents - Web pages - Reports
European Parliament: - Assessments from committees - Position papers - Legal text proposals
Reports from ACER and ENTSO-E
Databases: Eurobserver, Eurostat, lobbyfacts.eu
Annual reports of companies
Governmental reports
Grey literature, including: - IEA - High level commission on carbon pricing - REN21 - IRENA - Monopolkommission - Next Kraftwerke knowledge base - Various consultancies: Thema CG, Consentec, Agora Energiewende, Neon Neue Energie, Sandbag and others.
Newspapers, media: Euractiv, Politico, EUobserver, Energy Post, Tagesspiegel Energy and Climate

4.3.1.1 Public consultations

The main source of data for the first three papers of this thesis are publicly available consultation responses to the European Commission. The main consultation processes which serve as the background for paper 1 (Actor, policies and transitions pathways), 2 (ETS and RE policies) and 3 (EU coalitions) are the consultations for the RE directive and Electricity Market Directive. For paper 2, I also assessed consultation responses for the EU ETS reform process.

Given the large number of responses to the Commission, this is an extremely rich data set which allowed a comprehensive assessment of the positions of a large number of stakeholders. The consultation responses were used as the primary data source to depict what I denote as the "policy preferences" of key stakeholders in the policy process. A clear advantage of this procedure was that it was possible to abstract the main concerns and the main issues at stake for the actors. In a period with rapid change like in the third phase of the transition, it is important to take an explorative approach, since many of the issues at stake are not documented in the literature.

An alternative for retrieving data on policy preferences and policy core beliefs (for paper 3) is to carry out a survey. However, respondent rates for such surveys are often rather low. A survey type of study necessarily limits the focus of the survey to the specific topics identified beforehand.

There are two main caveats of relying mainly on consultation responses for assessing policy preferences. First, all actors do not provide sufficient data on all topics (i.e. the same issue as with a survey). In some instances, I was able to compensate for lack of information on one particular dimension by going through other documents published by an actor. Second, the responses by actors only provide limited information about why actors have the preferences they have. However, this issue can be addressed through additional interviews (see section 4.3.1.3).

Both paper 1 and paper 2 added information about explanatory factors through semi-structured interviews. For paper 4 (The Power of Power Markets), consultation responses were used as an additional data source to get an overview of the positions of a larger number of actors than covered in the interviews. Here, the data from public consultations was mainly used to support the findings from the interviews. It also confirmed the impression that the topic is politically sensitive within Germany. Of the responses to the public consultation carried out biannually by the Monopolkommission, only a handful of actors had agreed to publish their responses on the Monopolkommission's website.

4.3.1.2 The coding scheme

A key analytical tool for the first three papers has been a coding scheme (Huberman & Miles, 1994, p. 431). This too has been developed through an iterative approach. For paper 1, the coding scheme was developed through discussions with my co-authors. After exploring the data, I developed a first draft of the coding scheme, which was then discussed. Throughout the coding process, I modified the coding scheme many times in order to capture the main distinctions among the actors. The coding schemes for the second and third paper build partly on the coding scheme in paper 1.

For paper 1 and 3, coding was done by myself with the help of one research assistant, Gunn Birgitte Skoge Nygard. I was responsible for checking and controlling the coding, the aggregation of coding values and the results. The coding for paper 2 was done by myself. Here, too, the coding scheme was modified throughout the work with the paper, based, among other things, on feedback from the guest editor and the reviewers.

In paper 4, I did not code the data, but organized the findings according to lower-level concepts, categories and core categories. This too was an iterative process, in which categories were tested and amended in an iterative process. Overall, the research process largely followed the route described in Figure 5.

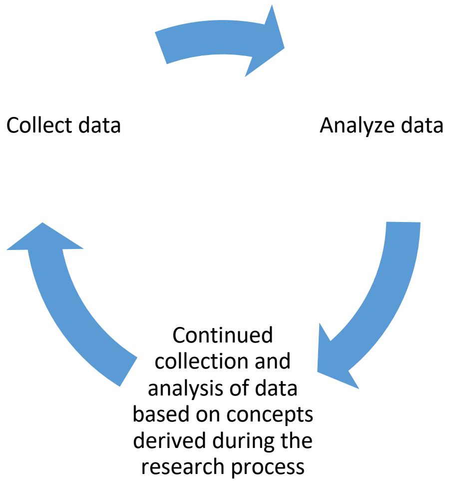

Figure 5: Diagram showing the iterative shifting between collecting and analyzing data (Corbin & Strauss, 2015, p. 8)

4.3.1.3 Interviews

For paper 1, 2 and 4, I use interviews as an important data source. In the period November 2017-January 2020, I carried out 32 interviews. Given that some insights from the first interviews helped determine the topics for paper 2 and paper 4, I was able to use some of the interviews for paper 1 for the subsequent papers as well.

In order to gain more background information on the topic, I also carried out several background talks in a more informal setting without recording. Table 7 lists all interviews conducted for this thesis, while Table 8 lists all the background talks.

Table 7: List of interviews

No.	Organization	Position	Date
1	Transmission System Operator	Head of European Affairs	November, 2017
2	Eurelectric – association for European electricity industry	1 Manager, 1 Senior Advisor	November, 2017
3	European Commission (B3)	1 Senior Policy Officer, 2 Policy Officers	November, 2017
4	Renewable Energy Association	Senior Analyst	November, 2017
5	European Commission (C1)	Policy Officer	November, 2017
6	European Commission (B2)	Senior Policy Officer	November, 2017
7	Renewable Energy Association	Policy Advisor	November, 2017
8	Nordic Transmission System Operator	Head of Legal Department	November, 2017
9	Utility 1	Head of Department	September, 2018
10	Utility 2	EU Regulatory affairs	January, 2019
11	Utility 3	EU Regulatory affairs	January, 2019
12	European Commission (former)	EU energy policy expert	January, 2019
13	German Think-Thank	Market expert	January, 2019
14	German Energy Exchange (EEX)	Managing Director	January, 2019
15	Nordic TSO	Special Advisor	January, 2019
16	German Think-Thank	Senior Associate	February 2019

17	German Institute for Market Affairs	Electricity Market Expert	February 2019
18	Nordic TSO	Senior Engineer market development	March 2019
19	Nordic Trading House	Head of Power Markets	March 2019
20	German Aggregator	Communication special advisor	March 2019
21	TSO Germany	Senior advisor, Manager energy market	April 2019
22	German Think-Thank	Senior Associate	April 2019
23	German RE organisation	Director	April 2019
24	German Research Institute	Market expert/economist	April 2019
25	TSO Germany	Senior Advisor	May 2019
26	German Aggregator	Communication special advisor	June 2019
27	Danish University	Market expert/scientist	August 2019
28	Nordic Utility	Senior Trader	August 2019
29	Nordic Regulator	Special Advisor	August 2019
30	German TSO	Senior Advisor	September 2019
31	Nordic Electricity Market Consultancy	Senior Analyst	October 2019
32	Nordic TSO	Senior Advisor transmission and market	January 2020

Table 8: List of Background Talks

No.	**Organization**	**Position**	**Date**
1	Nordic Aggregator	Leader of research and development	February 2017
2	European RE organization	Director	February 2017
3	Electricity Consultancy	Consultant	April 2017
4	Nordic Energy Exchange (Nord Pool)	Senior Consultant	March 2018
5	Nordic Utility	Executive Vice President	May 2018
6	Nordic Regulator	Market expert	January 2019
7	German Regulator	Advisor	February 2019
8	German Institute for Market Affairs	Electricity Market Expert	February 2019

All interviews were set up and conducted by myself. Interviewees were contacted by email or phone because of their assumed knowledge on the topic or their role in the policy process (purposive sampling) or due to recommendations from other knowledgeable persons or interviewees (snowball sampling). All interviews except three were recorded and transcribed afterwards for optimal accuracy and reliability. I took notes during all interviews and afterwards I would write short memos to capture the impression from the interview.

The interviews for the first two papers were semi-structured and followed a fixed set of questions. Before the first round of interviews, I did a 'test-interview' where I went through all questions with a fellow PhD candidate. Semi-structured interviews enable follow-up questions and allow interviewees to elaborate on their views. This approach was therefore well suited for the first two papers, where the overall objective of the interviews was to support the results from the analysis of the policy mix and provide explanations for the findings. However, these interviews also provided important knowledge about the political process, the main issues at stake and technical aspects.

The interviews for paper 4 were a mix of semi-structured and unstructured interviews. Even though they were planned as semi-structured interviews and I had sent questions to the interviewee beforehand, some of the interviews would unfold as unstructured interviews. I can confirm the findings of Grounded Theory scholars in this regard, that unstructured interviews provide the richest source of data for theory building (Corbin & Strauss, 2015). This was most important for the fourth paper, which aims at establishing typologies and Typology Theory. Given that market design is a highly technical issue, I used parts of some interviews to gain more information about the daily operation of traders and system operators.

Before every interview, I prepared well and examined as much of the written material that I could find or had been published by the interviewee (i.e. his/her organization) on the topic. Therefore, many of the interviews differ because my aim was to obtain as much information as possible from very different types of actors. In my experience, it is more important to be extremely well prepared and pose the right follow-up questions, than to have a perfect interview guide.

All interviewees were granted anonymity. This was important for most of them. A few interviewees were hesitant about being recorded, as these are sensitive issues for some actors. In all interview rounds, a few people did not respond to my request. For example, it was difficult to get access to large conventional utilities and high-level Government officials, but this has not affected the robustness of my findings. Almost everyone that responded agreed to participate. One actor declined because their organization did not have an employee that could answer my questions at the time. For some of the actors, it was difficult to find time for an interview during the busy period of policy negotiations for the Clean Energy Package.

4.3.2 Quantitative data

The quantitative data are important sources of facts on RE deployment, system operation, infrastructure and trading within the electricity sector. Most of this data is publicly available, but some was requested from the organizations. Table 9 provides an overview of quantitative data sources.

The survey was carried out during 2018-2019. Its main objective was to gather information about collaboration between non-governmental actors that seek to influence EU energy and climate policy. The details of the survey are specified in paper 3.

Table 9: Overview of quantitative sources of data in the thesis

Quantitative data
Survey among key actors, data collected 2018-2019
Electricity network and system operation data: - Nordic TSOs: Energinet, Statnett, Svenske Kraftnät - German national regulator (Bundesnetzagentur) - Nord Pool
Data on electricity trading: - European Energy Exchange - EPEX - Nord Pool - Nasdaq - Prospex Research 2018 - Montel
Data on renewable energy statistics: - Eurostat - REN21 - IRENA - Eurobserver

4.4 Philosophy of Science

4.4.1 Policy preferences

A key analytical entity throughout the thesis is 'policy preferences'. The concept of policy preferences is defined in various ways within public policy. Scharpf (2000) uses the notion "actor orientation" for actor preferences and perceptions and suggests treating these orientations as a theoretically distinct category. Different theoretical approaches differ in their views on what shapes policy preferences.

In the advocacy coalitions framework, scholars have developed a three-tiered system of hierarchical beliefs (Jenkins-Smith et al., 2014, p. 191). The "deep core beliefs" describe key properties of actors and involve fundamentally normative values and ontological assumptions that are independent of a specific policy area. At the next level, actors hold "policy core beliefs" that represents the basic orientation and value priorities for the policy systems. Finally, "secondary aspects" or "secondary beliefs" are preferences related to specific instruments and policy proposals (Hill & Varone, 2017). Secondary aspects within the ACF hence represent the "policy preferences" of actors, as an abbreviation for the preferences for specific policy means in order to achieve desired outcomes in policy core beliefs. In this thesis, I use the notion "policy preferences", since I do not rely strictly on the ACF in all papers.

Within sociological and historical institutionalism, scholars highlight that policy preferences are socially constructed and shaped by institutional norms and practices. (Berger & Luckmann, 1966; March & Olsen, 1989).

> Policy preferences are neither clear nor stable. They develop over time. They are shaped not only by forces exogenous to politics and decision making but also by the processes of politics themselves (March and Olsen, 1989, p. 146).

In contrast to institutionalists, rational choice scholars, including proponents of rational choice institutionalism, assume that policy preferences are exogenously given and stable over time (Scharpf, 2000).

This thesis takes the position that policy preferences are prone to change and that these changes can be induced by new knowledge and experience, but also through an interplay between exogenous forces and endogenous factors. I assume that actors have a bounded rationality, meaning that they are motivated by goals (corresponding to policy core beliefs), but are limited in their cognitive abilities to process stimuli such as information and experience (Simon 1957, 1985 in Jenkins-Smith et al., 2014). In other words, the ways in which these beliefs manifest is shaped by institutional conditions, but not determined by them.

4.4.2 Ontological reflections

The motivation for doing this thesis derives from my many years of working with climate policy. I have held different positions in various types of institutions (German Federal Ministry, environmental NGO, policy institute), working with climate policy on national and international levels. I have also published on several of the main topics within European and international climate policy (grey literature). This background was helpful in many ways because I had a good overview of the field and the issues at stake when I started. However, it also requires extra attention from my side through reflecting on my own positions in the encounter with different stakeholders.

It is important to note that my research is developed against the backdrop of climate science. This implies that I hold the findings of climate scientists to be real. I acknowledge the findings of the IPCC as the best estimates that science can currently produce with respect to emission reduction pathways and carbon budgets. To me, these are the facts that climate policy must relate to. As such, I take a positivistic position with respect to climate science as objective and observable knowledge.

As to the ontological foundations for my own research, I am very much aware of the role of the researcher in shaping the analysis. The work cannot be seen independently of the consciousness of the researcher and his/her perception of reality. This will affect the way data is interpreted, how the analysis is framed and the presentation of main findings. In this respect, I acknowledge the important insights derived from social constructivism (Berger & Luckmann, 1966). Nevertheless, I also believe that it is possible to make observations about physical and social reality and to assess its main features, albeit imperfectly. The thesis therefore takes the ontological position of critical realism. Critical realists acknowledge that real-world entities and causal forces may exist without anyone observing, knowing or constructing them (Patomäki & Wight, 2000). Bhaskar calls it an “empirical fallacy” to assume that only the empirically observable may count as real (Bhaskar, 1998, p. xii).

With the awareness of social constructivism in mind, researchers can and should continuously reflect on their own role as researchers and thereby do their best to achieve as precise an understanding of reality as possible. This is an ongoing process in which concepts are modified and improved.

4.5 Research ethics, reliability, validity

The research project was reported to the Norwegian Social Science Data Services (NSD) and follows their requirements in terms of data security for storing and processing the data. An overall priority has been to ensure sufficient privacy protection of the participants of this study. This is above all an issue for the interviewees and the survey respondents.

Indeed, the overall aim of the highest possible reliability of the findings can be at odds with ethical considerations. In order to protect the interviewees, I have considered it necessary to anonymize not only people, but also organizations. This is because I have mainly spoken to people in charge of EU policy affairs. Tracking them would be easy if the identity of each organization was known. For the fourth paper, the sensitivity of the issue within German politics made interviewees particularly conscious of the issue of anonymity. Several actors declined interview requests, and some were reluctant to permit recording. Other stressed that their organization did not have an official position on the topic, but they were willing to share their personal reflections regarding the pro and cons.

Several strategies have been pursued to achieve the greatest possible reliability and validity of the findings (Yin, 2014, pp. 45-49). Data has been cross-checked against each other and against other types of data to obtain the most accurate possible description of the situation. I have done my best to avoid researcher bias by checking and verifying statements from different interviewees. For example, information from interviewees would be confirmed with different type of media articles. Further, I have documented the steps of different research procedures and protocolled the development of the coding schemes and challenges that occurred during the coding process. An overall objective has been to take as many steps as operationally possible (Yin, 2014).

For the first two papers, the results were also 'tested' in some of the interviews, where interviewees were asked about the plausibility of the policy mix assessment. For the second paper, the interviewees were asked to give reasons for their respective policy preferences that could be observed in the assessment of public consultations. As to the fourth paper, some of the interviewees agreed to review the paper before it was submitted.

However, even though the great extent of anonymizing makes it difficult to replicate my study, validation of data depends largely on ensuring the most correct presentation of my findings and 'grounding' interpretations in data. In line with concepts of validation in qualitative research, validating refers to checking interpretations with participants and against data during the actual research process and altering or discarding interpretations that appear to be contradicted by incoming data (Corbin & Strauss, 2015, p. 65).

Finally, all references used are documented in the papers. I have followed the guidelines for good citation practice as listed in the Guidelines for Research Ethics by the Norwegian Research Ethics Committees (NESH, 2016).

5 Empirical context: The European energy transition

Empirically, the thesis explores current developments in European electricity policy. This is an area that has undergone large changes during the past decade and is hence of particular interest for transition researchers. The share of RE in the electricity sector rose from 14 % in 2004 to 32% in 2018 (eurostat, 2020a) and is expected to surpass 50% in 2030 (Schmid, Knopf, & Pechan, 2016). In 2010, the renewable industry had a turnover of €127 billion and employed 1.1 million people[10]. In 2018, total turnover amounted to €159 billion. Employment had grown to comprise 1.5 million direct and indirect jobs. Consequently, the sector has also increased its level of influence over EU policy.

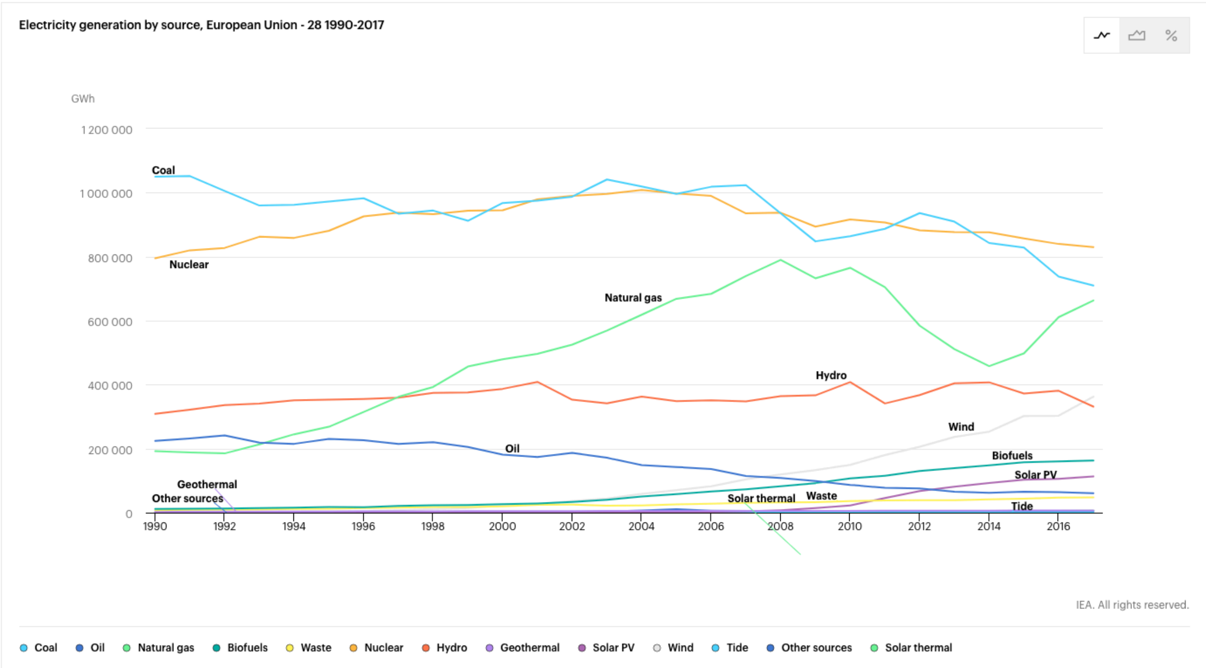

Figure 6: Electricity generation in the European Union by fuel source. (IEA, 2020)

Figure 6 shows the electricity generation by source in the European Union in the period 1990-2017. Several trends can be observed. During the period 2000-2010, there is increasing deployment of the 'new' renewable technologies, in particular for wind, solar PV and bio energy. The largest potential is expected for wind and solar, which have exhibited the steepest growth curves. At the same time, we observe that existing technologies have declined or remained stable throughout the period.

Even though wind and solar PV both are 'niche technologies', their level of deployment varies. Wind power generation more than quadrupled over the period 2005-2015, surpassing hydro power as the largest source of renewable electricity in 2017 (eurostat, 2017). In 2018, wind accounted for 36% of total renewable generation in the EU 28, whereas solar PV accounted for 12% (eurostat, 2020b). Solar PV is the third largest renewable source and the second largest 'niche renewable technology' in the EU after overtaking solid biofuels in 2013. The market shares of total electricity generation in 2018 were 11% for wind, 4% for solar PV and 3% for solid biofuels (eurostat, 2020b). However, as shown in Figure 7, these shares vary considerably across member states.

[10] Includes wind, biomass, heat pumps, solar PV, solar thermal, hydro power, biogas, biofuels, waste and geothermal.

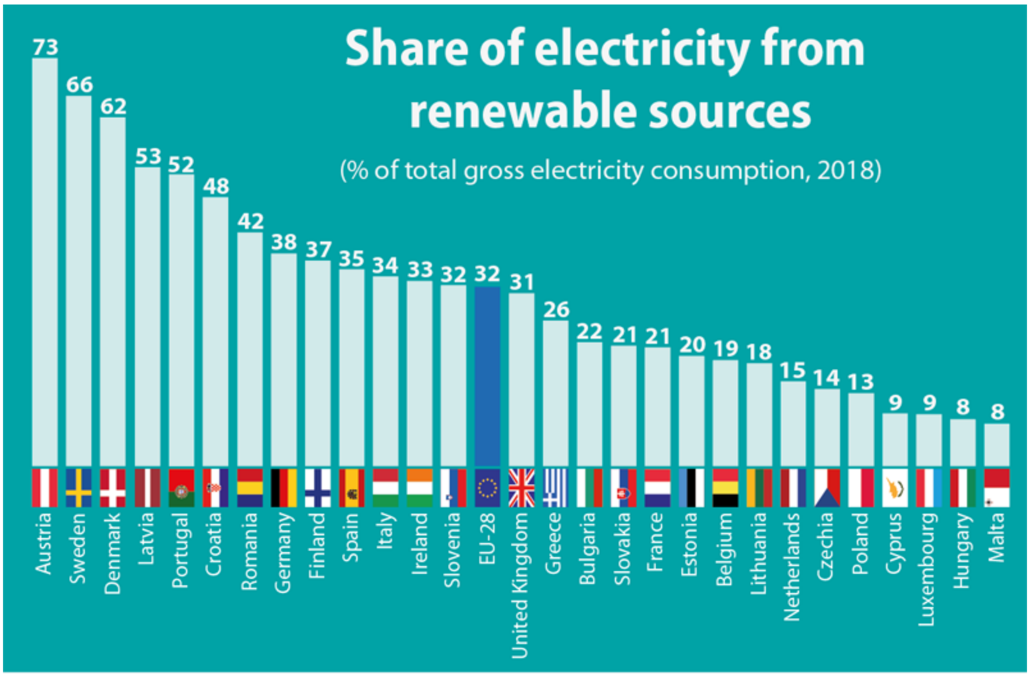

Figure 7: Share of renewable electricity in EU-28 and member states in 2018 (eurostat, 2020b)

Studying the European energy transition requires a demarcation of the technology at hand. My focus in the thesis is on what has been termed 'new' RE. This includes wind energy, solar PV, bio energy, geothermal, tidal and ocean energy, which I denote as 'niche technologies'. Existing technologies are coal (lignite and hard coal), nuclear, natural gas and hydro power. Hydro power is indeed also a renewable source, which plays an important role in the energy transition. However, it is not a new technology and the potential for further deployment in Europe is very limited. Electricity generation from hydro power has remained stable since 1990, see Figure 6. Some variation in hydro generation can be explained by variations in precipitation.

The role of nuclear power in the energy transition is contested. It is a low-carbon source of electricity, but its environmental impact in the form of nuclear waste and risks is considerable. As a result, some European countries have decided to phase out nuclear energy. Although the properties of conventional technologies vary to some extent, I operationalize the established electricity industry as representing *the regime level.* The regime comprises the technologies and the established institutions in the socio-technical system.

The remainder of this chapter explains the organization of EU energy and climate policy over the last decade (section 5.1), followed by an overview of ongoing system reconfiguration in the sector (section 5.2). Finally, section 5.3 elaborates on the role of market design for integration of RE.

5.1 EU energy and climate policy

EU energy policy pursues three main objectives: competitiveness, energy security and sustainability. This three-fold strategy was announced as key for a successful energy policy in the mid-00s (European Commission, 2006). In the Energy Union framework launched in 2015, these principles continue to play a seminal role. The Energy Union strategy specifies five dimensions; i) security and solidarity, ii) an integrated energy market, iii) energy efficiency, iv) decarbonization and v) research, "designed to bring greater energy security, sustainability and competitiveness" (European Commission, 2015b, p. 4).

Given the prominent role of the electricity sector when it comes to reducing GHG emissions, the sector is subject to a set of policies and regulations for emissions reductions and renewable energy deployment. Emission reduction is primarily regulated through the EU's emissions trading scheme (EU ETS), whereas RE targets and support are governed through the Renewable Energy Directive (RED). For an account of the historical development of the EU's climate and RE policies, see paper 2.

In the period 2010-2021, European legislation on the electricity sector was organized within two distinct 'packages'. Energy markets and electricity regulations were part of the Third Energy Package, the most important pieces of legislation being the electricity market directive (2009/72/EC) and the electricity regulation (EC No 714/2009)[11]. The Third Energy Package is characterized by two overall objectives; liberalization and the establishment of an internal market for electricity. Liberalization of the energy sector started already in some member states in the early '90s. The liberalization strategy was implemented in EU policy through the first electricity directive in 1996 (Dir 96/92/EC) and aims at increasing competition within the sector and strengthening the position of consumers. The idea of an internal electricity market originates from the Single European Act signed in 1986. This implies enhancing cross-border trade between EU member states and increasing capacities for electricity exchange through more interconnectors. Despite increasing trade and market coupling between European countries, it remains contested whether the internal market has yet been fully achieved (Glachant and Ruester, 2014).

Renewable energy, emissions reduction and climate targets were covered by the legislation in the '2020 Climate and Energy Package'. This package was developed to accommodate for the EU's 20-20-20 targets: 20% reduction in GHG emissions, 20% share of renewable energy and 20% increase in energy efficiency. The 2020 Climate and Energy Package contains several directives. The Renewable Energy Directive (Dir 2009/28/EC) has probably been the most important for the electricity sector with binding targets for renewable energy deployment for each member state and specific measures to support deployment. The ETS directive (Dir 2009/29/EC) has been important in that it covers emissions from the entire electricity sector. However, due to low prices throughout most of the period, it did not have a large impact.

As the legislation in these two packages was set to expire in 2020/2021, the EU started its negotiation for successive legislation in 2014. The empirical studies in this thesis therefore cover the period 2014-2018. During these years, the EU negotiated a set of new and revised directives and regulations. With exception of the EU ETS, all of these policies are included in the aforementioned large policy package known as CEP ("the Clean Energy Package for all Europeans") (European Commission, 2017). The EU ETS was revised in several steps in the ETS-reform process, which has come into effect in subsequent order.

A starting point for the empirical work has been the negotiations for this *Clean Energy Package*. During these negotiations, two important lines of dissent could be observed: One was an intense discussion over policies, the other was on how to change the market design to make "the market fit for renewables" (European Commission, 2015, p. 7). This time, the legislation on electricity markets and renewable energy was gathered into the same policy package. Furthermore, a new "governance regulation" was adopted to ensure coherence between policies and to keep track of target achievement.

The CEP makes important provisions for the development of the electricity sector until 2030. The negotiations for the CEP spanned a broad row of issues, including questions about continued renewable energy support, special treatment of renewable energy producers (or types of producers),

[11] Full name: "Regulation on conditions for access to the network for cross-border exchanges in electricity"

enhanced policies for cross-border trade, harmonization of national regulations to facilitate trade, changing market design and how to provide flexibility.

5.2 System reconfiguration

Along with increasing shares of RE in the electricity sector, the emphasis of the political struggles are shifting. In the earlier phases of the transition, the focus was largely on niche protection and nurturing. This was primarily ensured through RE support schemes and through shielding these technologies from certain obligations in the market that most other market actors have. In the current phase, the focus is still on RE deployment, but now also includes the systemic needs of the sector.

An important feature of the two main niche technologies, wind power and solar PV, is that their production varies a lot. As such, they differ from existing conventional electricity sources that can easily adjust their production according to current levels of consumption. Consequently, the entire electricity sector needs to be reconfigured to facilitate the integration of these new sources. This reconfiguration implies that the electricity system becomes more flexible, which means that it can easily respond to changes in electricity generation and consumption (Denholm & Hand, 2011; Steinke, Wolfrum, & Hoffmann, 2013). This is essential to maintaining a stable supply flow and can be done in different ways.

Sources of flexibility are production sources that can rapidly be ramped up and down (e.g. gas, hydro power), transmission grids, storage (batteries, power-to-X, pump storage), the combining of variable production within a specific area (virtual power plants or portfolio effects) and smart grids that enhance demand side response (Denholm & Hand, 2011; Nosratabadi, Hooshmand, & Gholipour, 2017; Schaber, Steinke, & Hamacher, 2012; Steinke et al., 2013). Paper 1 describes how flexible sources and technologies can be organized into centralized or decentralized solutions.

An important feature of the ongoing system change is the need to construct more grids, both on distribution and transmission levels. When it comes to the distribution grid, increasingly decentralized production implies that electricity is fed into the system on this level. At the same time, consumption increases when other sectors, like transport and heating, shift their energy use to electricity. On the transmission level, there is a mounting need for new lines. The entire energy transition involves a shift in where much of the electricity is produced and more transportation capacity is needed. As conventional power plants in the vicinity of densely populated areas are decommissioned, large amounts of electricity from remote wind parks must be transported over longer distances. Therefore, all European countries have ambitious plans for how to strengthen their electricity networks in the coming decade (ENTSO-E & ENTSOG, 2020).

Electricity grids on the distribution and transmission level are important sources of flexibility for two main reasons. Through so-called smart grids, consumers can become more flexible in that they can shift or reduce their demand at times of scarce supply. This requires consumers to be willing to adjust their behavior and for the necessary equipment to be installed. The potential of so-called demand-side management is highly uncertain (Lindberg, Seljom, Madsen, Fischer, & Korpås, 2019; Matschoss, Bayer, Thomas, & Marian, 2019). Further, more grids on the transmission level provides flexibility because electricity can be imported from other areas with excess production or available storage resources. Most studies find that importing/exporting electricity (i.e. electricity exchange) between areas with shortage/excess supply is a cost-efficient way to make the electricity system more flexible, especially because storage solutions are more expensive and often involve high efficiency losses (Schaber et al., 2012; Steinke et al., 2013).

5.3 A market fit for renewables

The configuration of the electricity system is intimately connected with the electricity market design. This is particularly important for the components system operation and electricity networks. In other words, how system operation is carried out and how the grids are constructed and managed varies with how the market is designed. In order to capture the political aspects of market design, scholars should devote more attention to the processes through which regulation for electricity grids and system operation are developed. Since these regulations are highly technical, it might be challenging to discern the political considerations that guide them, or even determine their direction.

As noted above, a key strategy for the EU has been to establish an internal market for electricity. In order to ensure cross-border trade abides by 'fair' conditions, the EU makes provisions about many aspects of the electricity market. Hence, RE support and exemption from market rules have large consequences for competition and how the market works.

During the CEP negotiations, the Commission advocated that the market should be 'the main tool' for the energy transition:

> Both the European Council and the European Parliament have repeatedly stressed that a well-functioning integrated energy market is the best tool to guarantee affordable energy prices, secure energy supplies and to allow for the integration and development of larger volumes of electricity produced from renewable sources in a cost efficient manner. (European Commission, 2016, p. 2)

Given that renewable energy technologies possess different characteristics than conventional power production, one key objective of the European Commission has been to make the "market fit for renewables" (European Commission, 2015, p. 7). However, the question of what the properties of such a market should be is highly contested.

Since the Third Energy Package, the European Commission has pursued the strategy of the "Target Electricity Model" (Newbery, 2016). This implies that the integrated internal market for electricity should follow an energy-only market design. This is a market that does not allow capacity mechanisms[12]. Instead, the European Commission has advocated that the energy-only market is sufficient to provide a secure and reliable electricity supply. Moreover, it was concerned that capacity mechanisms would distort cross-border electricity trade and competition (Leiren, Szulecki, Rayner, & Banet, 2019). The issue of capacity mechanisms was a critical point during the CEP negotiations. Several member states and incumbents strongly advocated for keeping capacity mechanisms. Critics argued that this would be a way for conventional electricity producers to secure income streams for polluting power plants (Bolton & Clausen, 2019). The final outcome of these negotiations was that generation capacity that emits more that 550g CO2/kwh is allowed to take advantage of capacity mechanisms. This is included in the regulation on the internal market for electricity, article 22, 4a (European Union, 2019).

This thesis does not engage with the issue of capacity mechanisms, which has been covered by several other studies (Bolton & Clausen, 2019; Leiren et al., 2019; Newbery, 2016). Rather, it explores the overall strategy of pursuing the energy-only Target Model. Notably, whereas several contributions have studied the market design as a question of the energy-only market versus capacity mechanisms, less attention has been devoted to the fact that the energy-only market can take various forms. Even

[12] Capacity mechanisms are specific payments for maintaining electricity production capacity outside the wholesale market. Power plants that participate in these mechanisms hence receive a remuneration for keeping production capacity available. This contradicts the principle of the energy-only market, where producers are paid for the amount of electricity that is actually produced and delivered in the market.

though the energy-only market is the ambition of the EU, considerable differences exist between energy-only market designs.

The last paper of the thesis (paper 4) investigates the energy-only market designs in the Nordic electricity market and in Germany. Since both regions have high shares of RE, they are very interesting for a comparative case study of market designs. Moreover, their energy-only models differ in several important ways, which makes them two ‘extreme’ cases. Germany has chosen a design with one large market area, whereas the Nordic market has many smaller market areas. Market areas are also called *bidding zones* or *price zones*.

According to Purchala (2019), the issue of market area configuration caused heated discussions during the CEP negotiations. However, in order to understand these dissensions, a general analysis of these two market models is required. The topic of zonal configuration in electricity market design is not yet sufficiently examined by transitions scholars. In general, financial and regulatory aspects of existing energy regimes tend to be poorly understood (Loorbach & Verbong, 2012, p. 238). Even in public policy or STS, the topic of electricity market design is underresearched (Silvast, 2017). Given the technical nature of the topic, these issues tend to be less accessible than general discussions on RE support schemes and targets. Nonetheless, it will be decisive for solving the challenges associated with decarbonizing the entire electricity sector. Consequently, Paper 4 is devoted to the issue of market design. The paper takes a step back to assess the two main types of zonal market design in Europe and examines how well they pair with the ongoing energy transition.

6 Research findings (paper presentation)

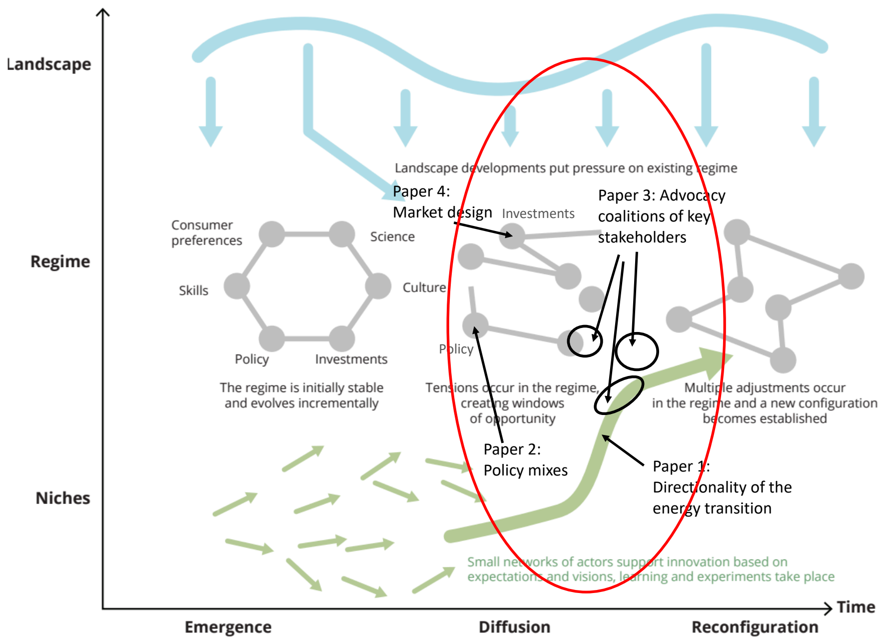

Figure 8: Illustration of how the four papers relate to the MLP in the third phase of the transition. Modified version of figure from EEA (2019).

In Figure 8, I have positioned the papers within the MLP framework. The red circle marks the third phase of the transition. The four papers study different aspects of the transition within this phase. Paper 1 assesses the policy mix for the transition and explores how the energy transition can take different pathways as a result of various policies and policy preferences. In particular, it studies how influential actors try to steer the transition in their preferred direction, which represents a less-disruptive pathway. Paper 2 builds on these findings and takes a closer look at the preferences of influential actors with respect to the ideal policy mix for the energy transition in the EU. This is especially relevant for the 'policy regime' dimension of the socio-technical regime. Paper 3 aims at providing a broader overview of the policy subsystem and main advocacy coalitions. The findings show how the ongoing transition influences the positions and preferences of key actors, but also how the main distinctions between niche and regime actors still prevail. Finally, the last paper explores the role of market design in advancing energy transitions. It does so by assessing to what degree existing market designs comply with the technological changes that follow from the transition. This relates to the 'market regime' dimension of the MLP.

6.1 Paper 1: Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix

Research question:

Which policies and which actors favor which kind of sustainability transition pathway in the EU's energy policy mix?

As the energy transition in Europe advances, the constellation of actors changes. This is in line with MLP-theory, which describes potential process dynamics for how regime actors might adopt new technologies and accommodate with new institutions (norms, rules). The changes within the regime can be observed empirically by studying the positions and preferences of key actors in the socio-technical system.

The paper combines an assessment of actors' preferences and the policy mix with respect to two overall dimensions: 1) RE ambition and 2) reconfiguration of the electricity system. In the analytical framework, we suggest that these two dimensions can be used as indicators for more general dimensions for assessing sustainability transitions pathways. These general dimensions are 1) sustainability and 2) disruption.

In order to study the latter, we develop a typology to explore the development toward increasing degrees of *decentralization versus centralization*. We establish these two concepts as ideal types for the reconfiguration of the electricity system, which represents opposing directions of an electricity system with high shares of RE. Through a comprehensive framework and coding scheme we systematize the three main components of the electricity system, i.e. electricity production, grids and system operation, into these two ideal-types. As such, we take a whole-system perspective on the electricity system and consider the configuration of the entire system. This approach rests on the assumption that the different parts of the system must be coordinated and addresses recent calls from transition scholars to take a whole-system perspective (McMeekin et al., 2019).

The analysis consists of two distinguished parts: an assessment of policy preferences of key stakeholders and of EU electricity policies. Both parts are assessed with respect to the two main dimensions: RE ambition and centralization versus decentralization. The main data set for actor preferences are consultation responses to the European Commission submitted in 2015 and 2016. The assessment of the extant policy mix includes the main EU policies for the electricity sector as of 2015. Seven interviews with representatives from the key stakeholders were used to confirm the main findings of the two assessments.

The findings show that with the renewable energy and energy efficiency directives, adopted in 2009 and 2012 respectively, strong decentralized elements were introduced in the policy mix on the production side. At the same time, the incentives to accommodate for more decentralized production in the grids and system operation parts of the electricity system have been weak or absent. This was seen as a large tension in the policy mix. Policy officers in the European Commission expressed that this was a primary issue for the Clean Energy Package. The paper shows that if we integrate more decentralized production into the electricity system, the other parts of the system must accommodate for this. Otherwise the system becomes increasingly unstable. Moreover, it illustrates the need to take a whole-system perspective when analyzing transition pathways. The politics related to system configuration of the electricity system is elaborated further in paper 4.

The results of the two-part analysis and its synthesis provided several insights about the ongoing energy transition. First, we find considerable support for continued renewable energy deployment. A majority of actors support the energy transition. There is, however, considerable disagreement with respect to their concrete ambition, i.e. the pace of RE deployment and the size of RE targets. This corresponds to the general trends in the electricity sector: As more companies invest in RE, they establish RE departments and RE actors are becoming more influential as their market shares increase.

However, we find more disagreement about the reconfiguration of the electricity sector and whether we should pursue more decentralized or centralized solutions. Interestingly, most actors with high RE ambitions have strong preferences for more decentralization and argue that this is a precondition for succeeding with the transition as such. We also find that most actors that are considered as 'highly influential' prefer more centralized configurations. They try to pull the energy transition in a more centralized direction, which eventually means less disruption for incumbent actors. This is in line with the findings of paper 2, to which I turn next.

6.2 Paper 2: The EU Emissions Trading System and Renewable Energy Policies: Friends or Foes in the European Policy Mix?

Research question:

Why do different actors hold substantially different policy preferences toward the ETS and RES support – and are preferences consistent across policy processes?

This paper builds on the work in paper 1 and the assessment of the policy mix for the energy transition in the EU. It follows the recommendation from Flanagan et al. (2011) to identify the main tensions in the policy mix. The RE directive (RED) and the ETS are two of the EU's main policies for reducing emissions in the electricity sector. Even though the policies diverge in their overall policy objectives – the RED aims to increase RE shares in order to reduce emissions, whereas the ETS regulates a cap-and-trade system for emission reductions – they can both be considered key *transition policies*.

The contentious relationship between the ETS and RE support lies at the heart of the politics of the EU's energy transition (Fitch-Roy, 2017; Lehmann & Gawel, 2013; Meckling, 2011). Since the origins of the EU's coordinated climate policy in the 1990s, there has been a continuous debate about which measures should ensure that the EU achieves its joint target for emissions reduction[13]. Even though economists have argued that a cap-and-trade system is the most cost-efficient way to reduce emissions (Goulder, 2013) and that additional renewable support in a sector which is already covered by a cap-and-trade system will have no effect on total emissions (Böhringer & Rosendahl, 2010; Jarke & Perino, 2017), a technology-specific advocacy coalition managed to ensure continued and targeted support for RE technologies (Cointe & Nadaï, 2018).

One contribution of this paper is to document how the two policies – ETS and RED – correspond to different policy approaches as described in section 2.4.3. The ETS represents a market-based approach (approach B), whereas the RED is designed in line with the principles of innovation policy approaches (approach C). The findings illustrate how different types of actors evaluate the policy mix in radically different ways. Whereas the RE actors and environmental NGOs perceive the ETS and renewable support as consistent and coherent, industry associations, utilities and traders argue that they are highly inconsistent and incoherent. Above all, this is a result of the different logics underlying the policies, but the policy element design of the respective policies also had an impact.

The paper documents the diverging positions of groups of actors in three policy processes in a systematic manner. It shows how the policy preferences of one important group of actors, i.e. the utilities, vary across policy processes as a result of advancing transition dynamics. This is interesting, because these actors can be considered core regime actors within the electricity sector. In the CEP negotiations, about half of the actors in this group shifted their positions and argued that these two policies – ETS and RED – could and should coexist in the policy mix. In-depth interviews with some of the actors in the respective groups revealed that this was largely a result of these actors now investing in RE themselves. At the same time, the actors highlight how the ETS helps them in two ways: First, it makes fossil electricity production more expensive. Second, as a result of the first, it leads to an increase in the electricity price on the wholesale market, yielding higher revenues for electricity

[13] The EU's climate policy is built on an effort sharing principle, by which all member states must contribute with individual emission reductions. The EU's commitment to the Kyoto Protocol was a joint emissions reduction target to reduce emissions by 8% by 2012, compared to 1990-levels. The EU has also a joint pledge to the Paris Agreement, currently 40% reduction by 2030 compared to 1990-levels.

producers with low emissions (RE and nuclear). Therefore, RE producers profit from high CO_2 prices and a strong ETS.

This shows the effect of increasing market shares in the third phase of the energy transition regarding the preferences and strategies of key regime actors. The regime actors are engaging with the niche technology to a larger degree. Some of the regime actors have even become major RE players. Theoretically, these are incumbents that have de-aligned with the existing regime as suggested by Geels and Schot's (2007) de- and re-alignment pathway.

Moreover, the paper illustrates the need to assess the effect of policies within phase 3. Whereas transition scholars have pointed to the need for policy approaches that encourage innovation and niche protection in early phases, the incumbents that have de-aligned with the regime argue that a strong ETS helps them in their activities. Because their technology is so well developed, a carbon price is sufficient to help them in the market. In this respect, the situation is very different in phase 3. A main problem identified in phase 1 and 2 was that pollution charges would not be sufficient to drive technology development. In phase 3, this is no longer the primary need for niche actors. Instead, pollution charges might enable the 'mature' niche actors to compete with conventional technologies in the market.

6.3 Paper 3: The rise of the *nigime*? An assessment of advocacy coalitions in an advancing energy transition

Research question:

What are the main coalitions within EU electricity policy and how can coalition structures inform transition scholarship?

The third paper applies the ACF (Sabatier 1998, 2007) and explores synergy effects with the MLP. We identify advocacy coalitions through a cluster analysis of main *policy core* beliefs among key non-governmental actors. This exercise tells us about the main lines of distinction within the policy subsystem and enables us to observe how main coalitions have changed over the course of a transition.

Previous studies from the political science literature characterized the RE coalition as much smaller and weaker (Gullberg, 2013). In the period 2005-2009 the coalitions on the niche and regime levels were very distinct (Boasson & Wettestad, 2013). Ydersbond (2018) identifies three coalitions in the period 2013-2014 during the negotiations for the 2030 Energy and Climate Framework: the broad green coalition, the electricity industry and the energy-intensive industry.

In contrast to these earlier studies, we find five main advocacy coalitions. These are: 'RE industry', 'Industry', 'Environmental Niche', 'Conventional Electricity Industry' and 'Progressive Electricity Industry'. Our detailed assessment of policy core beliefs reveals that actors differ along several policy core belief dimensions. For some actors, these beliefs have shifted compared to earlier phases of the transition. What used to be the 'electricity industry' has split into a progressive and conventional coalition. In the former 'green' coalition, we identify a distinction between environmental organizations and renewable industry associations. The latter are approaching the progressive utilities in terms of similar policy beliefs. Together, they constitute a new emerging regime, which we term *nigime*.

A particular feature of the nigime is that these actors combine strong beliefs for state intervention with strong market beliefs. This represents a shift from actor orientations in previous coalitions, where niche actors advocated the former and regime actors the latter. From an ACF perspective, this is highly interesting, since the ACF presents these beliefs as contradictory orientations on one and the same belief dimension.

For the coalitions with the most extreme positions, i.e. the 'environmental niche' and 'industry' coalitions, the traditional market versus state dichotomy still prevails: Industry actors perceive policies as detrimental to well-functioning markets and E-NGOs are critical about the ability of markets for solving the challenges ahead.

Whereas earlier studies of advancing transitions have focused overly on the *strategies of incumbents* in a transition (Geels, 2014; van Mossel et al., 2018), we provide important insights about the strategies of niche actors that are moving into the nigime. From primarily being occupied with advocating their advantages in the market (i.e. niche protection and nurturing) in early phases of the transition, they now increase their efforts regarding the need to change the *regime configurations* (i.e. market design and infrastructure). During the CEP negotiations, the wind industry advocated that their technology should have access to all types of markets and highlighted the need to adjust market rules to accommodate for their variable production (Wind Europe, 2017).

However, it is important to highlight that both nigime and niche actors (E-NGOs, RE industry, progressive utilities and smart energy actors) agree that strong state intervention and policy targets are essential. Our study points to a sustained need for state intervention also in the third (diffusion) phase of sustainability transitions, even after niche technologies have reached certain market thresholds. This implies that sustainability transitions strongly rely on state intervention throughout the entire transition.

The findings show that although the fossil regime is losing ground, transition pathways and policy measures in EU energy policy that should pave the way for full decarbonization of the energy sector by 2050 are highly contested.

6.4 Paper 4: The power of power markets: How do zonal market designs comply with advancing energy transitions?

Research question:

How do zonal electricity market designs differ and what are the implications for the energy transition?

Finally, the fourth paper assesses the role of market design in advancing energy transitions. When the shares of RE technologies in the electricity system increase, market design becomes increasingly important. The paper explores the interlinkages between electricity market design and whole system configuration of the electricity system, focusing on the two components, *electricity networks* and *system operation*. It rests on the understanding that the way the market is designed will eventually determine how the grids are constructed and how the system is operated.

The paper makes a novel contribution to the literature on sustainability transitions in that it explicitly integrates market design as a study object. The topic of electricity market design is not yet sufficiently examined by transitions scholars. The paper develops a typology for zonal markets and identifies the main strategies, ideas and institutional logics of the different market designs. Further, it suggests four criteria for assessing the compatibility of market design with advancing energy transitions. These are: flexibility, portfolio effects, system costs and hedging opportunities.

The ideal types for zonal market designs are based on two European regions: Germany with one single price zone and the Nordic countries, who are divided into 11 zones[14]. Both markets have gone from high shares of conventional energy to reach RE shares exceeding 40% of total consumption during the past 20 years (Eikeland & Inderberg, 2016; Leiren & Reimer, 2018).

Through a large number of expert interviews and an assessment of public documents and national statistics, I compare market design and system configuration in these two regions. Based on the findings, I identify two ideal types for zonal market designs that vary with respect to their overall strategy, main idea and dominant institutional logic: the 'copper plate approach' – exemplified by Germany with one, national zone, and 'regional cooperation' – exemplified through the Nordic market with numerous, smaller zones.

One important finding is that market design in the two regions varies substantially according to the respective criteria. Drawing on institutionalist perspectives, these designs can be characterized as two different models that are organized around different institutional logics. The 'copper plate approach' follows a 'trading' logic with the objective of enabling unlimited trade within the entire zone regardless of physical limitations in the system. The 'regional cooperation' adheres to a 'market~physics' logics, pursuing large degree of compliance between physical electricity flow and market trade. Nordic and German actors adhere to these dominant logics to a large degree.

Notably, perceptions on what kind of market design is the most efficient and best functioning vary substantially. There is broad support for their respective designs and resistance towards change. Both regions exhibit a high degree of institutional inertia and taken-for-grantedness, illustrated by actors who express strong support for their own respective model without necessarily questioning many of the established practices.

The paper finds that the 'regional cooperation' is much better aligned with the energy transition in terms of the first three criteria: flexibility, portfolio effects and system costs. Overall, 'regional cooperation' provides a more correct spot price and is better suited to integrating renewable energies into the system from an operational point of view. The 'copper plate approach' has much higher system costs, but very good hedging possibilities in the futures market. This becomes increasingly important when subsidies for RE are shortened and developers must look for alternative ways to secure themselves toward price risks. However, the effect on futures market liquidity and potential remedies for that is contested. However, the topic is highly contentious. Institutional differences in the two regions have resulted in very different perceptions of what a good market model actually is.

Overall, the paper shows that market design has large implications for domestic energy transition strategies, including RE support, network construction and electricity exchange. As the configuration of the electricity system is intimately connected with the electricity market design, it is important for transition scholars to identify the implications of different options for the energy transition.

[14] The entire Nordic market consist of 15 zones, as Finland and the Baltic countries still have national zones. The main focus of this paper is therefore the market model in Norway, Sweden and Denmark.

7 Discussion: Implications of findings for transition theory

> Ten years ago, few people would have bet on such disruptive development in renewable energy. Today, green resources are driving the energy transition, thanks to cheaper but advanced technologies and an increased environmental awareness. In this context, Enel Green Power, born as a bet, a dream, a great challenge, is now a victory, a reality, a challenge that goes on and keeps on being engaging (Enel Green Power, 2019).

The quote above comes from Enel, an incumbent nigime actor identified in the thesis. It is illustrative of the work of this thesis in many respects. It demonstrates the rapid changes in the energy sector during the past decade. At the same time, Enel's position embodies a belief that the transition is becoming increasingly self-sustaining. As such, Enel represents one particular transition pathway which was identified in this thesis – a centralized pathway in which small-scale production is less important.

The papers within this thesis have studied the policies, actor preferences and market designs in the European energy transition. Indeed, the findings show that the energy transition has reached a new stage in which technological change is an important driver of the transition. At the same time, the picture is much more complex and contentious that one might think from the quote by Enel above. The papers identify several important tensions and lines of conflict within European electricity policy in the third phase of the energy transition. This provides important insights, both for transition studies and social energy research.

These insights will be discussed in the subsequent sections. Section 6.1 discusses the role of different policy approaches in advancing transitions and relates this discussion to the typology of policy approaches presented in section 2.4.3. This is followed by a discussion of when technologies can be considered 'market mature' in section 6.2. In section 6.3, I elaborate on the importance of market design for regime reconfiguration in phase 3 of a transition. Finally, the choice of policies and market design has major implications for the direction of a transition, which is discussed in section 6.4.

7.1 Policy approaches in phase 3

Is there a particular role for policies in phase 3 of a sustainability transition? As already pointed out, transition scholars have underscored the need for technology-specific policy instruments in the first two phases of a transition (Jacobsson & Lauber, 2006; Kemp et al., 1998; Sandén & Azar, 2005). This corresponds to the Policy Approach C, i.e. 'technology development/early adoption' (see Table 4, section 2.4.3). In particular, scholars have highlighted the advantages of niche protection and nurturing compared to policy instruments that give priority to cost-efficiency (Azar & Sandén, 2011).

However, as noted in 2.4.3, other policies might also play an important role in driving the transition. Moreover, the effect of policy instruments that follow particular logics will play out differently in phase 3. Paper 2 shows how the policy preferences toward policy instruments change rapidly in this phase. The emerging nigime identified in paper 3 advocates strong state intervention for decarbonization and renewable deployment, but also highlights the need for market-based approaches and amended market design. As such, this coalition actively tries to change the regime structures. The composition of the nigime broadly matches the coalition of progressive utilities in paper 2, which preferred continued use of RE support policies (Policy Approach C) in combination with emissions trading (Policy Approach B).

The findings of this thesis show that we still need policies in phase 3 of a transition, but that the policy mix for phase 3 might need to embrace different types and combinations of policy instruments than earlier phases. The policies must find the right balance between technology-support (Policy Approach

C) and making (conventional) regime technology more expensive (Policy Approach B). Moreover, they must address the inherent bias in existing institutional arrangements. Given that an existing regime is constructed and configured to facilitate existing technology, we need to change the inherent structures of the regime.

Although there have been numerous studies of policy mixes for sustainability transitions in the past years, little attention has been devoted to the question of which types of instruments could help the niche technologies in the diffusion phase, and under what conditions. In other words, they have not discussed policy mixes for phase 3 as something *qualitatively different* from phase 1 and 2. Recent studies address the need for destabilization and phase out of existing technologies, so-called *strategies of 'creative destruction'* (Kivimaa & Kern, 2016; Leipprand & Flachsland, 2018; Normann, 2019). Such exit strategies imply the prohibition of specific technologies in the future, corresponding to the command-and-control policy approach A. However, paper 2 shows that market-based policies (policy approach B) can also play an important role when it comes to regime destabilization. For incumbents that engage with niche technologies, the ETS is an important tool for them to become more competitive.

A core argument of transition scholars against policy instruments that apply the polluter-pays principle (Policy Approach B) has been that it is difficult to get a sufficiently high emissions price or pollution charge that would have an effect on technological change. The tax levels or permit prices required to meet emission reduction targets are not sufficient to spur the development of more advanced technologies, to prepare for new infrastructure and to decrease consumption levels (Sandén & Azar, 2005). However, as RE technologies approach cost competitiveness with conventional technologies (IRENA, 2018), the needs of niche technologies change. Indeed, conventional technologies still have the advantage that existing institutions and infrastructure are configured to meet their needs. The legal system, tax regimes and market designs have evolved around specific technologies to enable the functioning of a socio-technical system. Existing technologies even receive substantial subsidies. In 2018, fossil fuel subsidies amounted to more than 400 billion dollars (IEA, 2019a). However, the disadvantage of the newcomer technology can be significantly mitigated by pollution charges, even at moderate levels.

The advantage of pollution charges in phase 3 of the transition is that they do not have to be sufficiently high to spur and enable technology development. Instead, their role in phase 3 is to provide a level playing field for all market participants and to ensure sustained technology deployment. The findings in paper 2 show that in earlier phases of the energy transition in Europe, RE actors strongly advocated technology-specific support. Now, they also discuss how pollution charges from the ETS might help them in their businesses. Notably, this is the case for large utilities that have entered into RE. This is already observed with carbon price levels at €25/ton, as discussed in paper 2.

7.2 Actors' preferences and market maturity

In phase 3, the perceptions among key actors shift. New lines of contestation can be observed. Along with an advancing energy transition characterized by improved competitiveness of RE technologies, there is a growing debate around whether it is the right time to abandon RE support (Schmidt et al., 2019). Paper 3 assesses how key actors and coalitions differentiate by four dimensions of conflicting policy core beliefs. Three of these dimensions concern the role and scope of markets and policies. Whereas nigime and niche actors argue that we still need strong state intervention, regime actors advocate a phase-out of RE support policies. The position of regime actors is justified by the argument that RE technology is *market mature.*

The concept of market maturity is directly linked to improved cost-competitiveness of new innovation technologies. Market maturity implies that a new technology is 'mature' to compete in the market on equal terms with other technologies. Consequently, the need for any type of policy within policy approach C becomes redundant. Often, this is defined as grid parity, the time point at which the cost of the new renewable electricity intersects with the cost of electricity generated from conventional fuels. Gu Choi, Yong Park, Park, and Chul Hong (2015, p. 718) note that "it is generally thought that, without any subsidies, a renewable energy technology will have cost-competitiveness in the market when the technology reaches the 'grid parity' point".

Market maturity of RE technologies depends on several factors, including the level of carbon pricing as shown in paper 2, interest rate levels (Schmidt et al., 2019), electricity price levels and variability in the wholesale market (Kraan, Kramer, Nikolic, Chappin, & Koning, 2019) and the ability of RE producers to secure their income streams over a longer period (Criscuolo & Menon, 2015). Whether a technology is actually market mature is context dependent, in the sense that available resources and geographical conditions affect the costs of the technologies (both existing and newcomers). It also depends on the extent to which (the costs of) externalities are internalized in the value chain through market-based instruments (policy approach B).

Further, the different character and nature of specific technologies, infrastructure configuration and market design will also influence a technology's ability to compete. Acknowledging that the price levels and opportunities to secure income streams are interrelated with market designs, market maturity is not an objective entity that can be assessed independently of how the entire socio-technical system is organized. Paper 1 and paper 4 show how system configuration and market design greatly influence the functioning of existing policies, and how they enable different types of transition pathways.

Papers 1 and 4 show that the configuration of the electricity system and market design will affect the capability to integrate high shares of RE. Small-scale technologies like household PV will require a different type of configuration than large off-shore wind parks. However, this is not only a question of technology characteristics. Who the deployers of a technology are and what resources they possess is as important in this respect, as discussed in paper 1. Private citizens and energy communities have different preconditions when they invest in renewable energy than internationally operating energy companies. Hence, they will respond differently to specific policy instruments. In paper 1, we see that the incumbents prefer market-based instruments like auctioning and the ETS, which suits their business models better.

Many of the aspects that affect perceptions of market maturity are interrelated with the discussion about the correct policy mixes for phase 3 of a transition, as discussed above. It relates to phase 3 because this is the period when the technologies start to compete with existing technologies on price. And it explicitly illustrates the consequences of policy mixes in phase 3 and the need for theorizing on policy mixes according to *their effects on regime and niche actors*, respectively.

The MLP concepts are fruitful for analyzing the different aspects of market maturity. In an MLP perspective, the disadvantages of a newcomer technology are illustrated through the regime notion. The regime concept is ideal for conceptualizing the inherent privileges of an existing technology. Regime institutions evolve around regime technologies and help the regime to reproduce.

Consequently, the inherent characteristics of the established regime directly affect market maturity rates of niche technologies. Some policy instruments will change the competitiveness of existing regime technologies. Notably, policy instruments that pursue a market-based (policy approach B) will affect the market maturity of technologies differently than instruments promoting technology development (policy approach C). Market-based policies place a disadvantage on existing technologies and, hence, help the new technologies to become more market mature. Pollutions charges will indirectly affect the market maturity of new (clean) technologies by making existing technologies more expensive.

The identification of the nigime as the emerging niche-oriented new regime and its preferences for sustained support policies has important implications for MLP theory and the understanding of the niche level. Whereas prevailing definitions highlight the market thresholds as indicating when a new technology has reached a critical mass, the thesis shows that even though several of the new renewable technologies are well beyond these thresholds, their continued deployment depends on different types of policies and state intervention. In other words, the niche technology might have transformed into an emerging regime (i.e., into a nigime) in terms of market share, but is still dependent on renewed forms of state intervention adjusted to the mature and advanced stage of the transition. In other words, sustained support is still needed to achieve sustainability targets. This implies a decoupling of niche thresholds from niche (or nigime) support policies.

7.3 Market design and system reconfiguration

The thesis finds that system reconfiguration becomes increasingly important, as suggested by transition scholars (McMeekin et al., 2019). Paper 1 shows how the different parts of the system can experience various degrees of reconfiguration. We find different degrees of decentralization in the production, grids and system operation components. An important task for policy makers in the energy transition is therefore to ensure alignment between the various components of the electricity system.

In phase 3, where the technology design has stabilized and a niche has gained momentum, an important research task is to identify different options for amending regime institutions to make them more receptive for diffusing newcomer technologies. There is a growing body of literature investigating the challenge of integrating variable RE into the electricity system (Sinsel, Riemke, & Hoffmann, 2020). Yet, the role of market design is often neglected in this context. With a few exceptions from the adjacent field of 'science and technology studies' (Breslau, 2013; Silvast, 2017) little attention has been devoted to the question of market design and transitions.

In the thesis, I consider market design as an inherent part of the socio-technical regime. The market is an institution that contributes to maintaining and reproducing the regime. New technologies might have different characteristics and needs in terms of infrastructure and market design. Hence, they are often disadvantaged, in the sense that institutions, infrastructure and whole-system configuration is shaped to serve – and preserve – existing technologies. Paper 3 shows that the nigime coalitions mobilize their resources in order to change the market design. At the same time, members hold strong state intervention beliefs. The earlier dichotomy 'market versus state', which has been prevalent especially within political science, is therefore weakened for these actors. Their strategy is both to preserve strong regulatory policy measures while at the same time changing the market to accommodate their own needs. Changing the market design is hence an important part of changing the rules of the game (i.e. regime) and making the regime 'fit for the niche'. Or, in the words of the European Commission, creating a "market fit for renewables" (European Commission, 2015, p. 7).

In paper 4, I find that the design and structure of the electricity market constitutes a key feature of the electricity system. The market design has large impacts on the ability of an existing system to absorb greater amounts of new technologies. Market design affects all the components of the electricity system that we study in paper 1 – production, grids and system operation. Consequently, we need to understand the technical rules and regulations of the electricity system, as already pointed out by transition scholars (Bolton et al., 2019).

Another important insight from paper 4 is that the market design interacts with the policy mix. Therefore, specific policies and policy instruments might play out differently in systems with different market designs. The most prominent example in the thesis is the design of RE support schemes in Germany. If Germany changed its market design, it would have lower prices in areas with excess wind production. This would increase the costs of RE support, because this support is granted as the difference between a fixed remuneration level and the (variable) market price. The lower the market price, the higher the amount that must be granted in the form of state remuneration. Scholars should therefore take market designs into account when assessing policy mixes for transitions.

7.4 Competing pathways and the role of incumbents

The energy transition assessed in this thesis involves a number of different niche technologies, of which the most important are solar PV and wind (see chapter 5). Due to their technical properties, various niche technologies have different needs. The thesis shows that in Phase 3 of a transition, there might be a competition between different types of niche technologies.

Building on existing assessments of electricity infrastructure (Funcke & Bauknecht, 2016), Paper 1 identifies two potentially competing directions of the energy transition, i.e. *decentralization* and *centralization*. It establishes ideal types for these two categories and systematizes different energy technologies into these two categories. However, this is not necessarily a competition between solar and wind energy. Rather, the distinction is between large-scale, remote power plants and smaller-scale, decentralized production units.

There are several reasons why some technologies are prioritized and it is important to distinguish between the main drivers. One obvious reason is technological superiority in terms of price performance, accessibility and safety[15]. Another is that certain influential actors favor one technology because of their vested interests. Actors will prioritize certain technologies and try to influence policy-making for the benefit of their own interests, i.e. their competences and business models. Because of their proximity to policy makers, incumbents are in a much better position to influence policy-making processes (Geels, 2014).

Although we probably need a mix of different types of production technologies to cover future energy demand, paper 1 identifies the development toward increasing decentralization as an important line of conflict within the European electricity sector. Indeed, whether Europe prioritizes one pathway over the other will largely be the result of deliberate policy choices. Given that small-scale plants depend on continued support and market protection to a larger extent, the removal of such instruments would give priority to incumbent actors and a centralized transition pathway. Therefore, the two directions represent various degrees of disruption.

Moreover, the choice of policy approaches will influence the directionality of the transition. Policy approaches C (technology development) and D (networking) are important when it comes to bringing new types of actors into the energy transition. A strategy which relies solely on policy approach A (command-and-control) and B (market-based) is more likely to involve a less disruptive transition.

One example for the conflict over transition pathways during the CEP negotiations is the contested issue of market protection for small-scale players. The example illustrates how niche technologies benefit from different types of policy instruments. During the negotiation process, the wind and solar

[15] The breakthrough of electrical vehicles compared to hydrogen vehicles in personal transport has been characterized as the result of EVs being more efficient (direct use of the energy without losses involved in converting electricity into fuel) and accessible because users can charge at home and are not reliant on filling stations.

PV industry (represented by their respective industry associations SolarPower Europe and Wind Europe) favored a heightening of the RE ambition in the EU, and also advocated binding targets on member state level[16]. However, when it came to some of the benefits of RE technologies in the electricity market, the two industries departed in their negotiating positions.

In the proposals for the CEP, the European Commission proposed to remove several advantages for RE producers, including what is called *priority dispatch.* As shown in paper 1, these policy instruments have been important drivers for increasing decentralization. In particular, these advantages for RE producers have been crucial for the solar PV technologies, which have been adopted by many small-scale actors, especially households and firms. Removing these benefits would therefore hit this group of power producers harder than others.

Consequently, the solar industry mobilized massively to retain the benefits for small-scale producers. Solar Power Europe initiated the campaign, "Small is beautiful", and proposed new wording for the Electricity Market Regulation (SolarPower Europe, 2018, 2019b). Many of these proposals were accepted and the new legislation provides exemptions for small renewable installations up to 400kW (200kW from 2026). Solar Power Europe presented this as a major achievement of their work during the CEP negotiations (SolarPower Europe, 2019a).

The wind industry was also a member of the "Small is beautiful" campaign, but for them, it was not at the core of their negotiating claims. Instead, they mobilized their resources for ensuring access of RE producers to all parts of the electricity market, including the day-ahead, intraday and balancing market. Because wind power is a technology with larger unit size, it is overly developed by companies and larger cooperatives. Hence, priority dispatch was not a major claim for them during the CEP negotiations (Wind Europe, 2017).

The issue of exemptions for small-scale producers shows how the different properties of niche technologies resulted in slightly different negotiating positions. It implies that niche technologies were market mature for large-scale projects at this stage of the energy transition but this was not the case for small-scale projects. This shows that market maturity varies among actors with different needs and resources.

The two positions correspond to slightly different transition pathways. Whereas the solar industry represents a strongly decentralized transition, the wind industry embodies a much larger degree of centralization. This concerns both the production and infrastructure component of the electricity system. The issue of priority dispatch shows how different design elements of particular policies can direct the transition in various ways.

One finding in paper 1 is that the utilities favor a more centralized configuration of the electricity system, whereas the RE industry and E-NGOs advocate more decentralized solutions. Thus, we assume that incumbents will favor centralized technologies because these are more compatible with their existing business models. As such, it corresponds to a less-disruptive pathway for these types of actors. Decentralized options typically involve smaller production units, which do not provide the same opportunities for incumbent firms. A decentralized pathway will therefore entail other dimensions, such as aspects of democracy, participation and empowerment, which are not only linked to the mere

[16] One key policy element design of the 2009 Renewable Energy Directive was that it specified binding RE targets for all MS. This has been highlighted as extremely important for RE deployment within the EU by the RE industry. Their preference in the Clean Energy Package was to keep these binding national targets. However, they did not succeed, and the revised Renewable Energy Directive only specifies a binding overall target for the EU (32% by 2030). Nevertheless, they managed to lift this ambition from the original 27% in the EU's 2030 Energy and Climate Framework adopted in 2014.

production of energy. Citizens might experience empowerment due to ownership of the transition, which again can lead to increased acceptance for it. It can also strengthen the feeling of social affiliation. And when citizens and communities take control of the energy transition, this has several side effects that can help the development so that targets are achieved. The literature on energy communities discusses these effects (Colell, 2019).

Finally, a last finding from paper 1 is that there might be different transition pathways for the *various components* of the system, i.e. the production, grids and system operation components. While the energy transition has caused significant disruption within the production component, regime actors are not challenged to the same extent within the other components. As to the pathway typology described by Geels and Schot (2007), current analyses focus largely on the production component. But there might be different pathways for separate components of the electricity system – the grids, system operation and user components – which is what we suggest in the first paper. Furthermore, paper 4 finds that the transition within the German electricity grids component is strongly centralized. This contradicts earlier studies of Germany's energy transitions, where scholars identify the German energy transition as a "substitution transition pathway", i.e. a pathway that unleashes new entrants (Geels et al., 2016). This is true with respect to production, but less so for grids and system operation.

8 Conclusion

This thesis sought answers to the overarching question: *How do policies, markets and actors' preferences change in the third, advancing phase of energy transitions?*

By approaching this question through various theoretical lenses and from different methodological perspectives, the thesis provides new insights into the dynamics in the third phase of a sustainability transition. Transition scholarship has argued that the third (diffusion) phase of the transition is characterized by many struggles on multiple dimensions (Geels, 2019). This thesis contributes to throwing light on several of the main tensions within the European electricity sector in its third phase.

8.1 Changing policy preferences and beliefs

The thesis shows that the relationship between markets and policies is changing in the third diffusion phase of the transition. Certain types of actors have changed their beliefs and preferences within short time periods. This is especially true for incumbents that have entered into niches. The thesis shows that incumbents that are actively engaging with niche technologies show stronger preference for RE support and argue that the ETS and RE support are compatible in the policy mix. In the terms of van Mossel et al. (2018) these incumbents choose to be "first to enter niches" or to "follow into niches". The second paper finds that the policy preferences of these incumbents represent a shift from previous policy processes where the same actors used to favor the ETS as the main policy tool for driving the transition.

The third paper used the ACF to identify the main advocacy coalitions in EU electricity policy during the third phase of the European energy transition. It identifies five main coalitions in the policy subsystem, which means that new coalitions have been formed compared to earlier phases of the transition. Earlier work has distinguished between two clearly distinct coalitions during the policy negotiations 10 years earlier (Boasson & Wettestad, 2013; Gullberg, 2013). We even find considerable movement compared to the situation in 2013-2014, when the EU negotiated its 2030 Energy and Climate Framework (Ydersbond, 2018). Whereas earlier negotiation processes were characterized by strong divisions, this constellation has changed considerably. Our detailed assessment finds that the picture has become more refined in the diffusion phase of the energy transition and the distinction between the 'old niche' actors (E-NGOs and RE industry) and 'old regime' actors (utilities and industry) is dissolving.

A main finding is that the two coalitions 'RE industry' and 'progressive electricity industry' exhibit increasingly similar beliefs. Therefore, we argue that that these two coalitions form a new level within the multi-level perspective. We label this the nigime. Together, they represent the new, emerging regime. The findings illustrate how niche and regime levels are approaching each other.

A key characteristic of the nigime is that that these actors combine strong beliefs for state intervention with strong market beliefs. This pairs well with the findings in paper 2, which identifies a 'new' group of progressive utilities who argue that the ETS and RE support should co-exist in the policy mix. Nigime actors want strong policy targets and regulatory policy instruments, but they also highlight the need for market-based approaches and work to actively "make the market fit for renewables". As such, the nigime represents something qualitatively new in climate and energy policy, overthrowing earlier oppositions of market-based versus regulatory and state-aid policies (Boasson & Wettestad, 2013).

Moreover, the findings imply that even though niche (or nigime) technologies are well beyond market thresholds for when a new technology has reached a critical mass, different types of policies and state intervention are still needed to ensure continued deployment of these new sustainable technologies. This implies a need for a decoupling of niche thresholds from niche (or nigime) support policies.

It is important to note that for the coalitions with the most extreme positions, i.e. the 'environmental niche' and 'industry' coalitions, the traditional market versus state dichotomy still prevails: Industry actors perceive policies as detrimental to well-functioning markets and E-NGOs are critical about the ability of markets for solving the challenges ahead. Many of the key differences can be found in detailed policy design elements and market regulation. The differences between actors are becoming more refined and subtle. In order to discern the various lines of conflict in the policy processes, scholars need to engage with the technical and regulatory issues of the energy system (Loorbach & Verbong, 2012).

An important finding is that the utilities are no longer as harmonized in their positions as earlier. Whereas (Ydersbond, 2018) identifies the electricity industry as one main coalition, this thesis catalogues the various strategies of utilities, where some are the first to enter or follow into niche technologies (van Mossel et al., 2018). This pairs well with recent studies which find that incumbents take an increasingly progressive role in the transition (Berggren et al., 2015; Steen & Weaver, 2017). In the European energy transition, utilities differ according to several important dimensions: the type and strength of RE support, whether capacity mechanisms are needed, the role of the ETS and climate ambition. The conventional utilities have larger vested interests within existing technologies and try to delay the transition. They are closer to the traditional industry associations, and together, they constitute the 'broader regime' level. This implies that, compared to the regime demarcation in chapter 2, the (old) regime coalition is becoming smaller and less influential.

8.2 The role of market design

The thesis shows that state intervention and policies will still play a crucial role in the coming stages of the transition. However, support schemes for niche technologies become less important and market design is turning into a key issue for succeeding with the energy transition. Therefore, I agree with scholars who argue that energy social research needs to engage much more with market design (Bolton et al., 2019; Silvast, 2017). The thesis makes an important contribution to this endeavor. In paper 4, I establish a framework for assessing the appropriateness of zonal market designs for the energy transition.

The findings in paper 4 show that, even though the EU has a strong vision for a harmonized European energy policy, electricity market designs vary considerably across member states. This has large implications for the ongoing decarbonization of the electricity system. The choice of market design affects the electricity flow between countries and regions and the capability to exploit synergy effects across European countries and regions. Electricity system experts find that electricity exchange between areas with shortage and those with excess supply is a cost-efficient way to make the electricity system more flexible, especially because storage solutions are more expensive and often entail high efficiency losses (Schaber et al., 2012; Steinke et al., 2013). Therefore, market designs that enable an improved utilization of resources through electricity exchange will promote the European energy transition.

The thesis shows how market design can simplify the integration of RE by increasing flexibility and bringing down system costs. Paper 4 compared the Nordic and German electricity market, which differ greatly in many ways. Notably, the Nordic market is divided into many smaller market areas (i.e. bidding zones) whereas Germany has only one. This means that the price in the German wholesale market is always the same for all market participants within the entire bidding zone.

The Nordic market is a market model which strongly emphasizes compatibility between the physical flow of electricity and market trade. The main idea is that price signals should reflect the physical situation of the electricity balance, i.e. production and consumption, and the capacity in the electricity grids at any given time. As such, the need for additional intervention by system operators is reduced to a minimum. At the same time, it provides a signal for grid-related flexibility for all market actors. From a system operation perspective, the Nordic market design is superior to the German. However, the German market is much better in terms of liquidity in the futures market. The futures market enables market participants to hedge their production in advance, which is increasingly important for RE producers as RE support schemes are phased out.

Different types of market design will affect what policies are needed, their costs and how different types of RE policies will work. One contribution of the thesis is to show how the market design influences price levels and hedging opportunities. As a result, market design and system configuration have large implications for whether RE can compete in the market. They even determine overall price levels and the cost allocation between producers and consumers. Policy mix assessments of transitions ought to consider these aspects. This type of energy social research is an important yet underexplored area of research that should complement technological feasibility studies and cost-benefit assessments.

Finally, the electricity market design has considerable implications for what kind of infrastructure we have and how it is utilized. At the same time, my findings show that the perception of what kind of market design is the most efficient and best functioning varies substantially. Hence, further research is needed to understand the many political and social aspects of market design.

8.3 Competing transition pathways

Whilst transition studies have highlighted intensifying struggles in the third diffusion phase, the thesis also points to important trends that imply less conflict. The first paper identifies increasing and broad support for the energy transition in the third phase. Where early phases of the energy transition were characterized by strong disagreement around RE support and targets, an increasing number of actors argue that we need both. At the same time, new lines of conflict can be observed. Different groups of actors disagree on the types of policies, whether certain RE technologies can be deemed market mature, the role of the ETS in the policy mix and which type of market design is the most appropriate for the energy transition. As such, the thesis finds that actors disagree with respect to *the pace and direction* of the transition.

This thesis shows how the various policy mixes and preferences of key actors correspond to different types of transitions pathways. As such, it provides evidence that there is considerable level of dissent regarding the direction of the ongoing transition. One overarching tension that can be observed is the trend toward increasing decentralization, which opposes the centralized configuration within the electricity system (Funcke & Bauknecht, 2016; Lilliestam & Hanger, 2016). The first paper assesses empirically how incumbent actors favor centralized technologies and configurations, whereas E-NGOs, RE industry and certain types of new entrants prefer decentralized options. The niche actors with the strongest 'environmental' positions argue that the energy transition can only succeed through more decentralization. They also have the strongest belief in state intervention.

The thesis shows that different sustainability transitions pathways are possible. Another central contribution of this thesis is that the directionality of transition pathways is closely related to the business models, financing opportunities and technological competences of actors. Incumbent actors favor other kinds of pathways to new entrants and may pursue various strategies in order to influence policy and regulation to the advantage of their preferred pathway direction. While Geels and Schot (2007) identify different pathways as resulting from the timing and nature of a transition and factors that are externally given to actors, recent literature shows that incumbent actors chose different strategies when confronted with emerging transitions (van Mossel et al., 2018). The findings imply that in advancing transitions, incumbents will reorient and actively work to pull the transition in their preferred direction.

Further, it might be that we need new types of policies and new policy combinations in order to maintain the momentum of the transition. Existing research has rightly pointed to the need for destabilizing policies that actively remove unsustainable technologies (Kivimaa & Kern, 2016; Leipprand & Flachsland, 2018). However, we need more knowledge about the effect of different types of policies in the third phase. This thesis suggests that market-based policies gain in importance in later phases of a transition. Yet the effects of transition policies vary according to technology and actor types. An excessive focus on market-based policies corresponds to a rather centralized pathway. If we want to keep small-scale deployment and democratic participation in the transition, this also requires deliberate policy decisions.

8.4 Implications for future research

My final remarks will address the relevance of this thesis for practice and policy. I believe that many of the findings are highly relevant for stakeholders, practitioners and policy makers in the energy sector and many of the interviewees were eager to hear about the findings of my work. The thesis sheds light on vital parts of the energy transition, which will become all the more important in the coming years. Indeed, market design has large consequences for electricity trading and system operation. Now, these activities are moving toward the heart of the energy transition.

The thesis is the result of a sincere wish to understand how we can shape, construct, promote and achieve the energy transition. The findings combine comprehensive analyses of the policy processes and actor strategies with a rigorous assessment of the techno-economic literature. Together, the four papers explain some of the important features of the electricity system and how these are perceived by different actors. This is relevant for many different societal groups that work with the energy transition: policy makers, companies, associations, civil society organizations and scholars.

The work in this thesis has shown how the established and fossil-based energy regime is losing ground. However, the transition is still highly contested. What Enel Green Power calls “a victory, a reality, a challenge that goes on and keeps on being engaging” (see chapter 7) is a battle which is not yet won. In the light of extremely limited carbon budgets and carbon-intensive economies, we are running out of time (IPCC, 2018). Therefore, we need systemic, comprehensive and detailed assessments of sustainability transitions world-wide. Scholars should avoid simplified presentations of the issues at stake yet aim at sufficient levels of abstraction that can identify structural barriers.

The avenue of future research is broad and complex. In order to change unsustainable socio-technical regimes, we need further research on the technical, financial, economic and social aspects of transitions. We need to combine techno-economic expertise with social science analysis in order to understand: What are the ‘real’ techno-economic constraints, and what are social, political and even psychological barriers to the energy transition? This is an endeavor which can only be solved through interdisciplinary research and collaboration.

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PART II:

The papers in the thesis