An Institutional Perspective on Residential Battery Storage Systems in Germany

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Accelerating Transition Dynamics in a Multi-System and Multi-Scalar Context

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Before embarking on my PhD journey, I had often heard that research processes are not straightforward but characterised by impredictabilities. After completing the project, I can strongly confirm that.

With the intention to combine my fascination for economic geography with my interest in the multifaceted topic of sustainability, I applied for a PhD position at the Catholic University of Eichstätt-Ingolstadt, which fortunately received positive feedback. The quiet and little town of Eichstätt promised complete concentration on scientific work. However, my PhD journey was marked by many unforeseen events. First, the application phase for DFG (*Deutsche Forschungsgemeinschaft*, German Research Foundation) funding took longer than expected. Due to a temporary position at the university's Center for Latin American Studies, a research focus on Latin America even seemed possible. After the DFG application has finally been approved, I decided to go with the originally envisaged plan and to focus on sustainability transitions with residential battery storage systems in Germany as an empirical case. Then we experienced Covid, which made travelling to conferences or conducting interviews in person impossible. However, the pandemic enabled completely new forms and sources of data collection, such as remote access to virtual meetings of industry associations. In 2022, a research stay at IFRO (Department of Food and Resource Economics) at the University of Copenhagen was eventually arranged. Facilitated by Covid, the possibility of working remotely and moving my life to Denmark was not far off. Not least due to this, a further research stay at CIRCLE (Centre for Innovation Research) at Lund University became possible. This made me realise the beauty of such unplanned journeys. Experiencing the exchange with colleagues in Copenhagen and Lund was very valuable to me. I am very grateful to Professor Teis Hansen and Professor Markus Grillitsch for making these research stays possible!

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Glossary of German actors and terms, acronyms, and abbreviations

BMWi	Bundesministerium für Wirtschaft und Energie / Federal Ministry for Economic Affairs and Energy (until 2021)
BMWK	Bundesministerium für Wirtschaft und Klimaschutz / Federal Ministry for Economic Affairs and Climate Action (from 2021 until 2025)
BNetzA	Bundesnetzagentur / Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railways
BSW Solar	Bundesverband Solarwirtschaft e.V. / German Solar Association
Bundesministerium der Justiz	Federal Ministry of Justice
Bündnis 90/Die Grünen	Alliance 90/The Greens (German political party)
BVES	Bundesverband Energiespeicher Systeme e.V. / German Energy Storage Systems Association
CDU	Christlich Demokratische Union Deutschlands / Christian Democratic Union of Germany (German political party)
Clearingstelle EEG KWKG	Neutral body for the out-of-court settlement of questions and disputes on specific electricity legislation in Germany
CSU	Christlich-Soziale Union in Bayern / Christian Social Union in Bavaria (German political party)
Destatis	German Federal Statistical Office
Direktvermarktung	Direct marketing
DSO	Distribution system operator
EEG	Erneuerbare-Energien-Gesetz / Renewable energy act (German legislation)
EnWG	Energiewirtschaftsgesetz / Energy industry act (German legislation)
EU	European Union
EUR-Lex	Official online database of European Union law
EV	Electric vehicles
FDP	Freie Demokratische Partei / Liberal Democrats (German political party)
FCR	Frequency Containment Reserve

Gesetze im Internet	Laws on the internet (Digital legal information services of the German Federal Ministry of Justice)
GW	Gigawatts
IW	Institutional work
KfW	KfW Entwicklungsbank / KfW Development Bank (German state-owned investment and development bank)
MEP	Member of the European Parliament
MLP	Multi-level perspective
NGO	Non-governmental organisation
PV	Photovoltaics
R&D	Research & Development
RED	Renewable Energy Directive (EU legislation)
SNM	Strategic niche management
SPD	Sozialdemokratische Partei Deutschlands / Social Democratic Party of Germany (German political party)
TIS	Technological innovation system
TSO	Transmission system operator
VDA	Verband der Automobilindustrie / German Association of the Automotive Industry

PART 1: Umbrella I

1 Introduction

Renewable energy sources made up 45.3%[1] of gross electricity consumption in the European Union (EU) in 2023 – more than 4 percentage points higher than in the previous year. This growth in renewable electricity largely results from an expansion of wind and solar power across the EU. Solar power represents the fastest-growing source, as it accounted for 20.5% of the total electricity generated from renewable sources in 2023 compared to a mere 1% in 2008 (Eurostat 2025).

In Germany, which represents the geographical context of the case study of this thesis, energy from renewable sources accounted for 52.2% of gross electricity consumption in 2023 (Eurostat 2025). Political targets stipulate a further expansion of this share. In 2024, the *Renewable Energy Act* (*Erneuerbare-Energien-Gesetz, EEG*) specifies that the share of renewable energy sources in gross electricity consumption should be 80% by 2030 (in spite of an increasing electricity consumption given the decarbonisation of sectors outside the electricity sector such as transport) (Bundesregierung 2025; BMWK 2023). As on the EU level, especially the development of solar power in Germany is highly dynamic. The German Federal Statistical Office *Destatis* reported around 3.4 million photovoltaic systems on roofs and properties in Germany with an installed capacity of around 81.5 GW in April 2024, which constitutes an increase in the number of installed systems of 29.8% compared to April 2023, and a 20.5% increase in installed capacity over the same period (Destatis 2025).

Electricity storage is considered a key element in a successful transition towards de-fossilised and renewable electricity systems with high security of supply, as storages are necessary for balancing fluctuations in the generation of renewable electricity by decoupling its production and consumption over time. Thus, avoiding overproduction and shortages of electricity stabilises the grid. This applies in particular to the highly fluctuating PV and wind electricity (BMWK 2024; BMWK 2023; Sterner & Bauer 2017).

Fluctuations in electricity generation have different temporal dimensions. While long-term storage facilities, such as hydrogen storage or oil and gas storages, compensate for seasonal fluctuations by storing electricity for several days, weeks or even years, short-term storage systems absorb and release electricity several times within a day, even within seconds (BMWK 2024, 2023; Sterner & Bauer 2017). In Germany, pumped hydro storage systems and battery storage systems are currently the most important technologies in use for short-term electricity storage (BMWK 2023). Battery storage systems are usually divided into three submarkets according to voltage level connection, nominal power, storage capacity and applications: residential storage systems (with a capacity of up to approximately 30 kWh), medium-sized industrial storage systems (30 - 1 MWh) and large-scale storage systems (over 1 MWh) (Figgener et al. 2020; see also chapter 3). This thesis is concerned with residential battery storage systems (further on referred to as residential storage systems).

The markets for battery storage systems show considerable dynamics. Especially regarding residential storage systems combined with photovoltaics, Germany is one of the pioneering markets given the above-mentioned expansion in PV electricity generation (BMWK 2023; Figgener et al. 2020; IRENA 2017). We have seen dynamic sales figures since the first decade of the new

[1] According to the Directive (EU) 2018/2001, the Eurostat values of hydro and wind power are normalised to account for annual weather variations. Hydro power is normalised over the last 15 years, whereas wind is normalised over the last 5 years, distinguishing between on-shore and off-shore wind normalisation (Eurostat 2025).

millennium, with a significant take-off in the first half of the last decade. At the end of 2024, more than 1.8 million residential storage systems have been installed in Germany (Bundesverband Solarwirtschaft e.V. 2025). The market has mainly been triggered by relatively high household electricity prices and falling or completely expiring feed-in tariffs for electricity produced by photovoltaics, which makes the self-consumption of photovoltaic power economically worthwhile (Figgener et al. 2020). Thus, the initially (and still) most common use case of residential storage systems has been *prosuming* (i.e., *pro*ducing and con*suming* simultaneously), which aims at enhancing the self-production and self-consumption of solar electricity in private households by storing surplus electricity beyond current consumption (BMWK 2023; Tepe et al. 2021; Figgener et al. 2020; Kairies et al. 2019).

Based on the above-mentioned prosuming, more extensive business models have been developed. Large numbers of digitally aggregated photovoltaic and storage systems (so-called *virtual power plants*) are able to provide a so-called frequency containment reserve (FCR). This means that variations of grid voltage can be balanced through storing or withdrawing electricity during times of interruption or overproduction (Becker et al. 2024; Sousa et al. 2019). Furthermore, such virtual power plants can take advantage of price volatility in international electricity trade through timed sales. Another potential use case are so-called *energy communities* including *energy sharing*. More concretely, third-party aggregators enable the members of these communities to sell and buy electricity from other peers depending on their current demand or surplus production (Blasch et al. 2021; Mlinarič et al. 2019).

However, the sharp increase in decentralised electricity generation poses challenges to the electricity grids, as in times of high solar irradiation and low power consumption large numbers of photovoltaic installations can result in overloaded grid sections. In this context, when being managed accordingly, residential storage systems are able to improve the grid integration of solar electricity by storing the midday peak of electricity generation in photovoltaic systems, thus, reducing their maximum feed-in power (Figgener et al. 2020; Kairies et al. 2019). Hence, the potential benefits of residential storage systems go beyond individual savings through self-consumption.

In order to fully exploit the potential of residential storage systems, the regulatory environment is considered a key factor. However, energy regulation is highly contested in the German context. Actors with a stake in the system (e.g., electricity utilities or storage manufacturers) blame the regulatory framework as being the main obstacle to more advanced business models and a better system integration of residential storage systems and photovoltaics. Consequently, these actors make efforts to induce institutional changes. Thereby, we observe attempts unfolding across systems with automobile system actors increasingly advancing into the electricity system also in terms of regulatory changes (see Article I). Furthermore, this case raises questions regarding the impact of legislation by the European Union (EU) and the translation of policies and narratives across governance levels (see Artcile II). Finally, we have seen striking changes of attitudes and perceptions regarding the potential of residential storage systems in the main regulatory bodies in Germany (see Article III). These developments are the broader points of departure for this thesis.

1.1 Aims and contributions of the thesis

Given the above elaborations, the empirics motivated this case study (Siggelkow 2007) and, thus, the main perspective, which focuses on institutions. To explore the empirical case, this thesis is anchored in the field of sustainability transitions (also referred to as transition studies or socio-technical system transitions). This body of literature, complemented by my geographical focus, allows for taking on an institutional perspective on systemic change processes and offers suitable conceptual lenses to investigate the drivers and barriers to the diffusion of residential storage systems in Germany.

Transition studies consider sectors as socio-technical configurations consisting of, among others, technologies, markets, user practices, cultural meanings, infrastructures, regulations and business models (Köhler et al. 2019; Markard et al. 2012). The underlying assumption is that the different elements co-evolve over long periods towards a well-established configuration that works (Markard & Truffer 2008; Kemp et al. 1998). Institutions are considered as the "rules of the game", while very stable and specific roles are known as socio-technical regimes (Fünfschilling 2019; Geels 2002). Given that transitions refer to changes in socio-technical regimes, one essential research interest of transition studies focuses on institutional change and processes of (de)institutionalisation.

Although institutional theory has been mobilised by many transition scholars, further empirical work is called for. For instance, Fünfschilling (2019) advocates further studies on institutional complexity and the semi-coherence of regimes in order to determine the most effective trigger for change (top-down state-driven regulations vs. institutional work for constructing new rationales through, for example, professional standards and norms, behavioural campaigns or educational and training activities). Furthermore, more research concerning the relevance of certain actor types is necessary, especially when it comes to the (changing) positions and strategies of incumbents (Madsen 2022b; Turnheim & Sovacool 2020; Fünfschilling 2019). In this context, the potential of structural preconditions, such as regime structures or positions in networks, for enabling actors to engage in institutional change processes merits further attention (Duygan et al. 2021b, 2019; Fünfschilling 2019). The benefits of a geographical lens have been unveiled in many contributions (Binz et al. 2020; Hansen & Coenen 2015; Murphy 2015). More precisely, an institutional perspective on the geography of transitions, especially regarding the multi-scalarity of transition trajectories and the role of agency and power in rescaling processes, promises novel insights (Madsen 2022a; Miörner & Binz 2021).[2]

Given the explanatory power of an institutional perspective and the still open avenues for research, the overall aim of this thesis is *to advance the conceptual foundations of the role of institutions in transition studies through empirical research focusing on the market for residential battery storage systems in Germany.* Under this overarching aim, the thesis aims at investigating more specific issues with respect to multi-system interactions, the rescaling of institutional rationales and the capacity of regulatory bodies.

The first research interest (see Article I) engages with the literature on multi-system interactions in transitions. As transition processes are not limited to isolated sectors, this debate focuses on cross-sectoral dynamics (e.g., regarding the electrification of individual transport). In this con-

[2] For a more detailed overview of the current state of research on transition studies, see chapter 2 and the corresponding articles (Part II).

text, the first paper addresses scholarly calls for a better understanding of couplings and interactions between multiple systems (Kanger et al. 2021; Rosenbloom 2020), in particular regarding the creation of institutional couplings (Andersen et al. 2023a; Löhr & Chlebna 2023). More precisely, more research is needed regarding the affiliation of actors succeeding in creating institutional couplings, i.e. their position within one of the systems or at their interface, which might potentially change the course of system boundaries at a site of multi-system interactions (Andersen et al. 2023a). Against this backdrop, the following research question has been formulated:

> *1. How do institutional work activities condition the specific reconfiguration of system boundaries at a site of multi-system interactions? Which actors and (sector-specific) endowments are associated with strong agency to create institutional couplings?*

The contribution of the thesis consists in developing a conceptual framework on the reconfiguration of system boundaries with particular attention to the position of actors (within or between systems). In order to explain strong agency for shifting system boundaries, the framework relies on the concept of institutional work (Lawrence & Suddaby 2006) along with associated enabling conditions (Duygan et al. 2019).

The second focus (see Article II) contributes to the literature on multi-scalarity in transitions, in particular on the notion of socio-institutional rescaling between governance levels (Grillitsch et al. 2025). Multi-scalarity in transitions constitutes a fast-growing debate with scholars arguing that regimes and niches cannot be self-evidently attributed to the global, national or local scale, but need to be understood as the result of dynamics playing out in various places and at different levels of governance. In this context, rescaling focuses on the diffusion of niche and regime rationales across space, but also across scales (Madsen 2022a; Miörner & Binz 2021). Despite recent contributions on the multi-scalarity in transitions (Madsen 2022a; Roebke et al. 2022; Miörner & Binz 2021; Bauer & Fünfschilling 2019; Kivimaa et al. 2019; Fünfschilling & Binz 2018), the agentic dimension of rescaling along with enabling and impeding factors remains largely unexplored. Consequently, the following research questions address this research gap:

> *2. How and why do actors engage in socio-institutional rescaling with the intention to foster transitions? Which actors engage at which scale in rescaling institutional rationales? While taking account of the structural context the actors are embedded in, what are enabling or impeding conditions for such institutional work?*

As a contribution to this debate, my research provides novel empirical insights on relevant actor types and their activities for socio-institutional rescaling, which are operationalised by means of the concept of institutional work (Lawrence & Suddaby 2006). Drawing on critical realist underpinnings, the case study further focuses on scalar barriers and opportunities for change that shape the purposes and possibilities of actors.

The third research interest (see Article III) shifts away from industry actors towards the regulatory bodies, while engaging with the literature on the acceleration phase of transitions, a debate that is currently gaining traction. More precisely, recent contributions focus on the challenges that might prevent the acceleration of transitions and require substantial efforts from multiple actors to address them, including from policymakers (Rogge & Goedeking 2024; Markard et al. 2020). However, the specific capacities of regulatory organisations needed to tackle acceleration challenges as well as their regulatory implications have not been covered by previous research. More generally, regulation has mostly been treated synonymously to policies

and discussed at a very high level of abstraction by most transition scholars. Given these shortcomings, the following research question has been raised for this thesis:

> *3. How do Germany's governing entities tackle the regulatory implications resulting from the acceleration challenges associated with the growing market for residential storage systems?*

Article III makes two main contributions. First, given the lack of conceptual clarity in studies on regulation and policies in socio-technical systems, the article provides a clear definition of 'regulation' to distinguish it from the overarching term 'policy'. Second, it develops an interdisciplinary analytical framework for conceptualising regulatory state capacity needed to respond to challenges unique to the acceleration phase, thereby bridging the literature on acceleration challenges and policy implications with the literature on transformative capacities.

1.2 Overview of articles

This thesis includes the following three articles, which have been co-authored by the stated colleagues and are at different stages in the review and publication process (Tab. 1). In-depth expert interviews and participant observation of industry association meetings serve as the empirical base for all three articles.

Table 1: Title, authors and status within the review and publication process of the articles included in this thesis.

Title	Authors	Status
Multi-system interactions and institutional work: Actor interactions at the interface of residential storage systems and electric vehicles in Germany	**Andrea Käsbohrer** (lead and corresponding author) **Teis Hansen**, University of Copenhagen **Hans-Martin Zademach**, Catholic University of Eichstätt-Ingolstadt	Published on 27 April 2024 in the peer-reviewed journal *Environmental Innovation and Societal Transitions*; https://doi.org/10.1016/j.eist.2024.100844
An agentic perspective on socio-institutional rescaling: Institutional work for fostering residential electricity storages in Germany and the EU	**Andrea Käsbohrer** (lead and corresponding author) **Markus Grillitsch**, Lund University **Hans-Martin Zademach**, Catholic University of Eichstätt-Ingolstadt	Submitted to the peer-reviewed journal *Environmental Innovation and Societal Transitions*, second round of reviewing.
Regulatory state capacity for accelerating net-zero transitions: Lessons learned from governing electricity storage in Germany	**Andrea Käsbohrer** (lead and corresponding author) **Karoline Rogge**, University of Sussex & Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe **Hans-Martin Zademach**, Catholic University of Eichstätt-Ingolstadt	Published on 31 May 2025 in the peer-reviewed journal *Energy Policy*; https://doi.org/10.1016/j.enpol.2025.114659

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Article I (*Multi-system interactions and institutional work: Actor interactions at the interface of residential storage systems and electric vehicles in Germany*) addresses the first research question. The paper contributes to the debate on multi-system interactions by shedding light on institutional work carried out by stakeholders in the electricity and mobility systems along with their sector-specific enabling conditions. Drawing on institutional work activities to create regulative couplings, the paper proposes a framework on changing system boundaries in multi-system contexts. Exploring the market for residential storage systems in Germany through the lens of this framework, the article investigates how system boundaries between the electricity and mobility systems change due to powerful incumbents leveraging their resources and engaging in institutional work in adjacent systems.

Article II (*An agentic perspective on socio-institutional rescaling: Institutional work for fostering residential electricity storages in Germany and the EU*) is concerned with the second research question. The paper focuses on the agentic dimension of rescaling shedding light on why, how and with which outcomes actors engage in socio-institutional rescaling through institutional work activities in order to foster the diffusion of residential storage system in Germany and at a European level. Furthermore, the actors' purposes and possibilities based on the scalar arrangement they are embedded in are taken into account. The article unpacks the most relevant actors along with their scalar embeddedness and institutional work activities and shows how scalar conditions, such as institutional semi-coherence, but also experiences and perceived expectations trigger or impede rescaling.

Article III (*Regulatory state capacity for accelerating net-zero transitions: Lessons learned from governing electricity storage in Germany*) relates to the third research question. The paper introduces the concept of regulatory state capacity required for inducing regulatory changes, which respond to challenges unique to the acceleration phase of transitions. In this context, the paper derives specific regulatory implications resulting from acceleration challenges. Undertaking an analysis of the main regulatory bodies in Germany, the research shows that a change in the regulatory state capacity can result from inside the organisation itself by a change in leadership or from a changing socio-technical environment.

Further publications as well as presentations at conferences and workshops, which resulted from this thesis, are listed in Appendix A.

1.3 Thesis outline

Beyond the three articles outlined above, this thesis consists of an introductory text, the *umbrella*. Part 1 includes the first part of the umbrella, part 2 contains the three submitted or published articles, and part 3 consists of the second part of the umbrella.

Following this introduction, part 1 offers a conceptual background to the research project introducing the field of sustainability transitions, as well as the institutional perspective on transitions in greater detail (chapter 2). Chapter 3 provides a brief overview of the empirical case of residential storage systems in Germany focusing on the market development and the regulatory environment. Chapter 4 continues by discussing the methodology, including the research process, ontological and epistemological underpinnings, as well as methods for data collection and analysis.

Part 2 presents the three above-mentioned articles in chapters 5, 6, and 7. Please note that these articles have been published and submitted as standalone papers, which means that each paper includes the common elements of scientific articles (literature review, a brief overview of the case study, methods, empirical findings, discussion and conclusion). Thus, some repetition in this synopsis is inevitable.

Part 3, finally, concludes by discussing the overarching conclusions of this research and by considering potential avenues for future research.

2 Conceptual foundations

Socio-technical system transitions represent the point of departure for this thesis. I take on an institutional perspective on transitions and mobilise insights from institutional theory, which, combined with geographical lenses, allow for scrutinising the dialectic relationship of stability and change within the individual articles. This chapter aims at presenting the general conceptual background, which the articles are based on.

2.1 Research on sustainability transitions

The debate on socio-technical system transitions is a vivid, multi-disciplinary field (Köhler et al. 2019; Markard et al. 2012), originating from innovation studies, science and technology studies, and evolutionary economics (Smith et al. 2010). A socio-technical transition refers to an array of processes that leads to a far-reaching shift in socio-technical systems. Sustainability transitions are characterised by a distinct normative orientation for change and refer to transformation processes, through which established socio-technical systems radically shift towards more sustainable modes of production and consumption (Fünfschilling 2019; Markard et al. 2012). The overarching aim of transitions research is to conceptualise and explain how, and by whom, radical changes can be initiated and steered (Markard & Rosenbloom 2022; Köhler et al. 2019).

Sectors that provide societal functions and services, such as transportation, energy and water supply, or waste management, are conceptualised as socio-technical systems (Markard et al. 2012). Such systems are complex configurations consisting of multiple elements, comprising, among others, technologies, markets, user practices, cultural meanings, infrastructures, regulations, business models, industry structures, as well as supply and distribution chains (Köhler et al. 2019; Markard et al. 2012). This broad variety of elements usually develops and aligns over time into a working socio-technical configuration characterised by very stable and specific rules of the game known as socio-technical regimes. Consequently, established systems tend to be rigid as well as innovation and change are considered path dependent (Markard & Rosenbloom 2022; Fünfschilling 2019; Geels 2002). Fundamental shifts require a range of elements and dimensions in the socio-technical system to change radically, which is expected to take decades to unfold (Markard et al. 2012). Hence, multi-dimensionality, co-evolution and systemness are key characteristics of socio-technical transitions (Fünfschilling 2019).

Furthermore, socio-technical transitions are regarded as multi-actor processes. A range of actors and social groups from academia, politics, industry or civil society are involved, pursuing their specific interests, values and beliefs, and endowed with various degrees of power, resources or skills. Many kinds of agency come to play (e.g., sense-making, strategic calculation, learning, making investments, conflict, power struggles, creating alliances), which makes transitions very complicated, long-term processes that cannot be comprehensively understood by single theories or disciplines (Köhler et al. 2019; Fünfschilling 2019). Concerning sustainability transitions in particular, these characteristics are reinforced due to a usually contested understanding of what is ultimately sustainable and the necessary reconciliation of different actor perspectives and interests (Fünfschilling 2019).

According to Fünfschilling (2019), the analytical leverage of research on sustainability transitions lies in understanding the interplay of stability and change, in other words, the way existing, established socio-technical systems work and how innovation and change can challenge

their nature and supremacy. Thus, research in the field of transition studies revolves around both analysing the inertia and path-dependency of socio-technical systems and explaining how radical innovation and change result in their transformation.

2.1.1 Regimes, niches, landscapes

Theoretical frameworks were developed to conceptualise and explain transitions, such as the multi-level perspective (MLP), technological innovation systems (TISs), strategic niche management (SNM) or transition management (Köhler et al. 2019; Markard & Truffer 2008; Bergek et al. 2008; Geels 2002, 2004).

While focusing on different research interests (explaining system change (MLP), technological innovation and diffusion (TIS) or management questions), these theoretical frameworks share the premise that the stability and persistence of socio-technical systems is usually attributed to the embeddedness of actors in structural environments. The notion of the socio-technical *regime* has most prominently grasped these structural environments, originating from the scholarship in evolutionary economics, which explains why innovation seems to follow specific technological trajectories in line with the shared cognitive rationalities, assumptions and expectations of different actors (Fünfschilling 2019). In transition studies, this idea has been amplified to not just include shared cognitive routines relating to technological paradigms, but all kinds of regulative, normative and cognitive institutions shared by a variety of actors, such as politicians, public servants, civil society etc. (Fünfschilling 2019; Geels 2004).

Notwithstanding these structural environments, actors are considered being engaged in shaping their environment and, thereby, also influencing processes of innovation and change. Transition scholars have associated technological innovation with "*interpretative flexibility*" and sense-making, rooted in social interaction and negotiation (Fünfschilling 2019, 221). In order to explain the sources of change and in particular the role of actors in these processes, the widely applied MLP has introduced two further analytical concepts: the technological *niche* and the socio-technical *landscape* (Geels 2002).

The technological niche is conceptualised as a less institutionalised setting protected from regime selection criteria (e.g., the military or with electric vehicles in various European countries in the 1990s), where more radical and disruptive socio-technical configurations can be created and tested. These new, alternative socio-technical configurations can eventually scale up and replace regimes (Geels 2002; 2004 based on Rip & Kemp 1998). Correspondingly, research in transition studies has focused on investigating favourable niche conditions. Research on SNM has aimed at explaining the role of experiments in triggering the development of new socio-technical configurations (Fünfschilling 2019; Smith & Raven 2012), which is still a haunted research theme (e.g., Roebke et al. 2022 on urban experiments in public transport).

By means of the socio-technical landscape, the MLP also considers external and exogenous pressures, such as cultural values, climate change, wars, crises, or industrial revolutions. These slowly changing elements affect multiple systems at a time and are even harder to change than regimes (Geels 2002). Traditionally, research has mostly focused on types of landscape pressures on regimes instead of scrutinising how single and multiple systems shape the landscape itself (Kanger & Schot 2019; Fünfschilling 2019). The recent debate on deep transitions addresses this shortcoming by pursuing a comprehensive theorisation of long-term multi-system co-evolution, involving long-term processes affecting the landscape (Kanger et al. 2021; Kanger & Schot 2019).

Taken together, the MLP understands socio-technical transitions as an interplay of these three levels. In short, niche actors develop an alternative socio-technical configuration. The socio-technical landscape then exerts pressure on the regime level. Finally, the ensuing destabilised regime allows for the breakthrough of the niche configuration (Geels 2004).

However, this early understanding of stability and change in the MLP has been criticised for overrating niches as the key locus of innovation and regime change, which some contributions (Miörner & Binz 2021; Geels 2011; Geels & Schot 2007) have referred to as the *bottom-up niche bias*. A rather rigid view of actors has been a further point of criticism, with regime actors being regarded as defending the "bad" prevailing regime configuration and niche actors promoting the "good" new elements. In addition, the empirical application of the MLP has been criticised for ignoring processes of agency and emphasising a structuralist account of transitions (Madsen 2022b; Geels 2011). In response, a more differentiated conceptualisation of transition dynamics, along with the mobilisation of new concepts from different fields and theories and the investigation of new topics, is developing (Strambach & Pflitsch 2020; Köhler et al. 2019). The following chapter provides an overview of the most prominent recent developments.

2.1.2 Towards a more diverse understanding of transitions

As a refinement of the MLP, Geels and Schot (2007) conceptualise a typology of transition paths, based on differences in the timing and nature of multi-level interactions (either reinforcing or disruptive). They argue that path-breaking innovation is not exclusively limited to niches but may also originate in the context of regimes. Hence, they begin to renounce the *bottom-up niche bias*. In a spatially more sensitive manner, the debate on the *multi-scalarity* of transitions further develops this critique rejecting the overemphasis on the niche as the local starting point of transitions (Miörner & Binz 2021; Binz et al. 2020; Fünfschilling & Binz 2018; Truffer & Binz 2017; see also Article II). It is argued that the traditional model of niche cumulation and upscaling to the local regime followed by broader spatial scales gives ontological priority to local and national levels (Miörner & Binz 2021). Instead, Miörner and Binz (2021) highlight the potential trajectory of *downscaling* a new field logic (e.g., standards for alternative sanitation) driven by a global actor network into (sub-)national contexts. Emphasising the transformation of regimes, the concept of *global regimes* (Fünfschilling & Binz 2018) stresses that institutional rationalities (international sector-specific rules, standards and best practices) can diffuse through international networks and, thereby, get legitimised beyond their immediate context of origin. Taken together, according to the multi-scalarity of transitions, niches and regimes should be understood as multi-scalar structures.

Moving beyond the dichotomy of radical and incremental change, Geels et al. (2016) incorporate a more nuanced view on change mechanisms into their work on transition pathways. Distinguishing four types of change mechanisms (layering, drift, conversion, and displacement), the authors stress the possibility of shifts between the transition pathways and the possible non-linearity of transitions, which are arguably characterised by uneven advances and setbacks as well as incremental and radical phases, based on changing coalitions, unintended consequences and learning processes. In light of their empirical cases of the transition towards low-carbon electricity in Germany and the UK, Geels et al. (2016) associate the pathways with a largely endogenous development instead of external landscape change. This focus on endogenous change is also found in research on agency and institutional change in transitions, which I elaborate on in more depth in chapter 2.2.2.

In a similar vein, *configurational theorising* differs from the MLP given its less rigid and categorical perspective on socio-technical transitions (Heiberg et al. 2022; Madsen 2022b). Instead of distinguishing between niches, regimes and landscapes, configurational theorising conceptualises socio-technical systems as organisational fields including technologies (Fünfschilling & Truffer 2014). In its original definition, organisational fields are defined as organisations that make up "*a recognized area of institutional life*", such as key suppliers, resource and product consumers, regulatory agencies, and other organisations that produce similar services and products (DiMaggio & Powell 1983, 148). It is argued that these organisational fields, i.e. socio-technical system, comprise different socio-technical configurations consisting of actors, institutions, and technologies that are institutionalised to different degrees. While the most institutionalised configuration is also considered the regime, configurational theorising regards regimes to be heterogeneous acknowledging context- and sector-specific characteristics (Heiberg et al. 2022). While, for instance, the water sector might be shaped by a very strong global regime structure (Fünfschilling & Truffer 2014), the energy sector shows considerable spatial variation across nation states in spite of transnationally agreed targets towards decarbonisation (MacKinnon et al. 2019; Ćetković & Buzogány 2016). Consequently, in configurational theorising, multiple transition trajectories are possible instead of solely the traditional transition of one niche replacing one regime. For instance, Madsen et al. (2022) apply a configurational perspective to the Danish waste sector for explaining frictions in a complex configurational set-up, namely the configurations of landfilling, incineration, recycling, chemical recycling and reuse. They introduce the concept of the *contestation axis* to show that considerable frictions between actors occur at other axes than between established regimes and emerging niches. Concerning this thesis, Article II takes sector-specific characteristics, in the sense of multiple configurations existing in the electricity systems across Europe, into account while analysing the impact of institutional semi-coherence on transition dynamics.

Furthermore, transition scholars have zoomed in on the role of particular actors, such as users, civil society actors, or firms (Löhr & Mattes 2022; Köhler et al. 2019). Particular attention has been dedicated to incumbent regime actors focusing, for instance, on their active resistance to transitions, but also on their reorientation when confronted with political and societal pressure or economic incentives (e.g., Ertelt & Kask 2024; Geels 2021; Hellsmark & Hansen 2020; Turnheim & Sovacool 2020; Steen & Weaver 2017; see also 2.2.2 on agency and institutional change). The contribution of this thesis to a more nuanced view on incumbency is evident in Article I and III and elaborated on more generally in the discussion (chapter 8.1.2). Similarly, interactions between actors have been the subject of contributions concerned with, for example, political coalitions (Duygan et al. 2021b; Hess 2014), the role of intermediary actors and system entanglers (Löhr & Chlebna 2023; Kivimaa et al. 2019), or collaborations between incumbent firms and new entrants (Geels et al. 2016).

Based on and along with these conceptual developments, insights from other fields have been mobilised in order to shed light on specific dimensions of transitions, such as (broadly speaking) power, agency and politics, governance, culture and social movements or ethical aspects (Köhler et al. 2019). Due to the objective of tackling current environmental and societal challenges, new streams and foci are constantly developing. Examples of rather new research directions (though also relating to established debates) are the destabilisation, decline, and phase-out of existing systems and regimes (e.g., Kivimaa et al. 2021; Kungl & Geels 2018; Kivimaa & Kern 2016), interactions between multiple systems such as electricity-transport, agriculture-transport, and heat-electricity (e.g., Andersen & Geels 2023; Rosenbloom 2020, 2019; Konrad

et al. 2008; see Article I), or the acceleration of transitions (e.g., Rogge & Goedeking 2024; Markard et al. 2020; see Article III).

In response to the critique that the MLP is neglecting agency and conflating structure and agency, more actor-oriented research has been advanced, also drawing on institutional theory (Madsen 2022b; Fünfschilling 2019). In the following chapter, I elaborate on the implications of an institutional perspective on sustainability transitions, which constitutes the main conceptual lens in explaining persistence and change manifested in the diffusion of residential storage systems throughout the whole project.

2.2 Taking on an institutional perspective on sustainability transitions

This chapter provides, first, a brief introduction into the conceptualisation of stability and change in institutional theory (2.2.1). This is followed by a review of the main developments regarding how institutional theory is mobilised by transition scholars (2.2.2).

2.2.1 Stability and change in institutional theory

Early contributions of organisational institutionalism[3] were concerned with the question of how institutions structure the behaviour of actors or the diffusion of practices, arguing that institutional settings affect the legitimate scope of action for actors. The diffusion of technologies, best practices or organisational forms is explained by the pressure to comply with or replicate institutional structures (Fünfschilling 2019; DiMaggio & Powell 1983). DiMaggio and Powell (1983) distinguish between coercive, normative and mimetic pressures resulting in the homogenisation of actors, practices and structures in an institutional setting. Coercive pressures are exerted by the state through regulations and administrative oversight. Normative pressures stem from the impact of professional standards and norms as well as education. Mimetic pressures are associated with times of high uncertainty when more routinised and taken-for-granted actions or the imitation of successful peers are at play. Similarly, the widely featured 'three pillars' of institutions (i.e. regulative, normative and cultural-cognitive) show how different forms of institutions and legitimacy affect actors and practices. Regulative institutions apply coercion and (legal) sanctioning, whereas normative institutions are associated with social shaming and exclusion in case of inappropriateness and incompatibility. Cultural-cognitive institutions go along with shared cultural frames allowing for sense-making and common understandings (Fünfschilling 2019; Lawrence & Suddaby 2006; Scott 1995).

Confronted with empirical insights, research has sought an explanation for action and institutional change given these assumed homogenising, pre-existing institutional structures. Besides extreme events like wars, financial crises or catastrophes, scholars have also acknowledged more endogenous reasons for institutional change, with two prominent streams of research. On the one hand, organisational fields can be fragmented and conflicting allowing for dynamics of

[3] While being aware of the conceptional insights on institutions and institutional change that economic geography offers (e.g., the bodies of literature on varieties of capitalism, innovation systems, evolutionary economic geography; Grillitsch 2015), I mainly refer to the scholarship on organisational institutionalism for this basic introduction (Greenwood et al. 2011; DiMaggio & Powell 1983). This is due to the fact that organisational institutionalism provides fruitful conceptualisations of the stabilisation and destabilisation of institutional structures (Fünfschilling 2019). Furthermore, conceptualisations stemming from organisational institutionalism represent the approaches mainly applied by the transitions community for explaining institutional change (Köhler et al. 2019).

agency and change. On the other hand, interests, agency and power of actors may be driving forces for creating, maintaining or disrupting institutions (Fünfschilling 2019).

Regarding the former mentioned fragmented and conflicting organisational fields, the existence of institutional pluralism and contradictions represents an important source of innovation and change. Institutional pluralism results from the prevalence of various institutional logics. These institutional logics refer to rationalities guiding behaviour, such as principles governing the selection of technologies, defining which actors' voices will be heard, shaping the scope of action of actors, or setting criteria of efficiency. Different sources, such as a specific industry or location, certain professions, particular issues and social movements, potentially result in the existence of more than one institutional logic and, thus, institutional pluralism in an organisational field. This overlap of institutional logics leads to complexity in a complementary or in some cases conflicting manner (Fünfschilling 2019; Fünfschilling & Truffer 2014; Greenwood et al. 2011). For example, multi-national enterprises aiming at incorporating corporate social responsibility practices might face country-specific laws and regulations and corresponding requirements in addition to differences in managerial expertise and organisational values (Marano & Kostova 2016). Against this backdrop, institutional complexity is assumed to open the door for institutional change as it provides multiple rationalities for actions and, thus, increases the legitimate scope for agency (Fünfschilling 2019).

Regarding the latter mentioned agency and power of actors as a source of institutional change, research is based on a less structural explanation (Fünfschilling 2019). Most importantly, the concepts of *institutional entrepreneurship* (Battilana et al. 2009; Battilana 2006) and *institutional work* (Lawrence et al. 2009; Lawrence & Suddaby 2006) have been the focus of interest.

Institutional entrepreneurship focuses on the conditions enabling agency in terms of actors' characteristics and field conditions. Institutional entrepreneurs can be (groups of) organisations as well as (groups of) individuals that leverage resources to create new or transform existing institutions (Battilana et al. 2009; Battilana 2006). Some studies highlight specific characteristics or abilities of institutional entrepreneurs, such as the relevance of socially skilled actors who are able to motivate and cooperate with others (Fünfschilling 2019). However, the representation of an institutional entrepreneur as a heroic and powerful individual has evoked much criticism in light of the missing consideration of the institutional embedding (Duygan et al. 2019; Battilana et al. 2009). In response, Battilana et al. (2009) focus on the social position of actors in a field arguing that an organisation at the periphery of a field might be enabled to induce institutional change due to a lighter embedding, whereas organisations in the centre might have better access to resources and networks.

Institutional work scrutinises specific activities in creating, maintaining or disrupting institutions (Lawrence et al. 2009; Lawrence & Suddaby 2006). The emphasis on practices allows for zooming in on the micro-level actions that heterogeneous actors are engaged with seeking to change institutions. Based on a review of the literature on individual and collective actors influencing institutional settings, Lawrence and Suddaby (2006) identified distinct practices, which aim at both the mobilisation of rather tangible resources, such as political power, money, knowledge or social capital, and the (de-)construction of rationales and discourses. While some practices have been associated with the creation of institutions (e.g., *advocacy, educating, changing normative associations*), the maintenance of institutions covers the idea of a constant need of ensuring compliance with existing institutions (e.g., by *policing* or *valourising and demonising* by means of negative and positive examples). Practices aiming at the disruption of institutions undermine the compliance of actors with institutions by making them less attractive

and delegitimising them (e.g., by *officially changing rewards and sanctions*). In the following, I will outline how these insights inform the theoretical advancement of sustainability transition studies, while referring to the articles of this thesis.

2.2.2 Institutional theory and sustainability transitions research

Given that both institutional theory and transition studies share the understanding of change as a dynamic interplay between structure and agency, institutional approaches have early on been part of conceptual thinking in transition studies (Geels 2004). While the basic analytical frameworks have relied on institutions to explain the stability of regimes by means of regulative, normative and cognitive rules and routines, more recent contributions aim at explaining structural change and agency by mobilising institutional theory (e.g., Löhr et al., 2022; Madsen et al., 2022; Kivimaa et al., 2021; Becker et al., 2021; Fünfschilling 2019). In order to nuance the conceptual underpinnings of my research, I will elaborate on the notions of institutional complexity and embedded agency in the context of sustainability transitions in the following.

Change triggered by institutional complexity and semi-coherent socio-technical regimes

Institutional theory has been widely used to strengthen the conceptualisation of socio-technical regimes, and, thus, the inertia and path-dependency of prevailing, dominant configurations (Fünfschilling 2019; Fünfschilling & Truffer 2014; Geels 2004). As proposed by institutional theory and elaborated on above, a certain reproduction and homogenisation of dominant actors, regulations, technologies, routines, values, norms or cultural expectations takes places within and across different socio-technical systems due to institutional pressures originating from regulative, normative and cultural-cognitive structures. The elements of a socio-technical system have evolved over long time periods and resulted in a specific cultural-cognitive rationality or, in other words, institutional logic that has manifested itself in concrete technologies, laws, standards, beliefs, etc. (Fünfschilling 2019; Fünfschilling & Binz 2018).

However, the institutional architecture of regimes also provides insights for explaining innovation and change. Regimes are considered as being characterised by institutional semi-coherence, i.e. internal tensions, disagreement and conflicts of interests resulting from rules of different sub-regimes (such as science, users and markets, socio-cultural regime) (Geels 2011). That means that socio-technical regimes differ in their degree of institutionalisation and coherence.[4] Some systems are characterised by one highly institutionalised and uncontested rationality, which has been in place over long time spans, whereas others comprise less clearly developed and institutionalised, or even conflicting, institutional structures. Focusing on this institutional complexity offers the possibility to conceptualise change from within the systems, arguing that highly semi-coherent regimes might be more likely to undergo radical transformation given available and legitimate alternative institutional rationalities (Fünfschilling 2019; Fünfschilling & Truffer 2014).

As mentioned above concerning the field level, the complexity of a regime depends on the industry or sector (e.g., transport, energy or water) it revolves around. Sectors are characterised

[4] According to Fünfschilling and Truffer (2014), the institutionalisation of a regime increases with the scale and scope of its diffusion (e.g., implementation across geographical or sectoral domains), its duration of existence, starkness (e.g., low controversy), invulnerability to social intervention (e.g., resistance towards innovations), internal coherence (e.g., few contradictions) and embeddedness (e.g., good fit with surrounding context). Furthermore, institutionalisation is expected to be highest when principles have been translated into binding formal or material structures in practice (e.g., policies, technologies, actors, financial investments or routines).

by semi-coherence, as institutional rationalities developed in different fields come to play. For instance, speaking of the water sector, Fünfschilling and Truffer (2014) allege influences from the professions of engineering and economics, the state, the market as well as subject areas like consumer safety and environmental sustainability. Article I illustrates institutional complexity due to different sectors involved, namely the electricity and automotive systems, and argues that the incompatibility between system-specific institutions motivates actors to create new institutional couplings (e.g., shared industry associations, regulations, and standards).

As a further dimension, multi-scalar processes of institutionalisation (see 2.1.2), in other words, the interplay between global regimes or niches and local material and institutional conditions, are considered to trigger the semi-coherence of regimes. The translation of a global rationality into a specific location and vice versa is expected to create contradictions and tensions, thus, increasing institutional semi-coherence (Fünfschilling & Binz 2018). Article II shows how translation processes between scales in the case of electricity market designs lead to institutional semi-coherence and elaborates on how institutional semi-coherence impedes or increases the agency of actors at specific scales.

Change resulting from agency

Regarding the role of actors and agency, transition scholars often refer to institutional entrepreneurship and institutional work in order to explain the institutionalisation, reproduction or de-institutionalisation of socio-technical configurations. In this context, scholars focus on actors and their specific activities for creating, maintaining or disrupting institutions (Madsen et al. 2022; Löhr & Chlebna 2023; Löhr et al. 2022; Duygan et al. 2019). Thus, these frameworks are highly suitable for explaining transition processes, since they allow for operationalising the institutionalisation of niches as well as the maintenance and destabilisation of regime structures (Löhr et al. 2022; Fünfschilling 2019).

Concerning niche dynamics, the institutionalisation of socio-technical configurations and corresponding institutional rationalities often requires extensive work from different actors, which, for instance, theorise about new knowledge, organise in networks, engage in lobbying and political work, or run education campaigns for changing normative associations (Löhr et al. 2022; Fünfschilling 2019; Binz et al. 2016). Thus, unstable and loosely connected elements can pass into a more aligned and legitimate configuration with well-established actors, values, practices, routines etc., which eventually represents an alternative to the existing regime (Fünfschilling & Truffer 2016). This thesis applies the concept of institutional work in order to explain how residential storage systems are established as part of a new configuration at the interface of the mobility and electricity systems (Article I) as well as through institutionalisation processes across scales (Article II).

As regards regimes, transition scholars shed light on how actors engage in maintaining and reproducing or destabilising and replacing regime structures. To maintain institutions, actors ensure compliance through enforcement, auditing and monitoring or highlight the advantages and moral underpinnings of existing institutions. In the transition context, disruption is usually understood as the replacement of a central, fossil-based incumbent-led system. Therefore, actors, for instance, engage in lobbying to remove privileges or challenge existing assumptions and beliefs (Löhr et al. 2022; Lawrence and Suddaby 2006).

As mentioned in chapter 2.1.2, previous research has dedicated particular attention to incumbent regime actors (e.g., Smink et al. 2015; Fünfschilling & Truffer 2014; Stenzel & Frenzel

2008). Challenging the implicit assumption of innovative niche actors and resisting regime actors (Madsen 2022b; Köhler et al. 2019), other contributions have drawn a more fine-grained picture of incumbent actors, showing that they can also reorient towards niche innovations (Ertelt & Kask 2024; Geels 2021; Hellsmark & Hansen 2020; Turnheim & Sovacool 2020; Steen & Weaver 2017). In this vein, related to multi-system interactions, Article I shows that particularly powerful incumbent actors (e.g., automotive manufacturers, electricity suppliers) are able to acquire knowledge and further resources for carrying out institutional work at the interface of two systems. In light of the prevalence of global value chains, Fünfschilling (2019) highlights international consultants and non-governmental organisations as well as multinational corporations as being crucial for regime changes. Moreover, given the role of public policy for the speed and direction of socio-technical transitions, it is crucial to focus on the strategies and activities of (incumbent) state actors (Borras et al. 2024; Edmondson et al. 2019). Article III elaborates on regulatory change capacity needed for tackling challenges of the acceleration phase of transitions and explains changes in the role of state actors.

3 Empirical background

This chapter aims to introduce the empirical background of my research. It starts with a brief introduction to electricity storage technologies Germany and to the market for residential storage systems in more detail. Subsequently, it presents the institutional context in terms of energy regulation in Germany and regarding the most relevant legislation at EU level.

3.1 Electricity storage technologies in Germany

As elaborated on in the introduction (chapter 1), the German electricity mix is characterised by a growing share of wind and particularly PV electricity, characterised by a rapid increase in the number and capacity of installed PV systems as well as ambitious political targets.

Electricity storages are necessary, in order to balance fluctuations in the generation of renewable electricity by decoupling its production and consumption over time and, thus, stabilise the electricity system and grids, especially regarding the highly volatile PV and wind electricity (BMWK 2024; 2023; Sterner & Bauer 2017). Storage technologies are usually differentiated into short-term and long-term storages. Long-term storage facilities, such as pumped hydro storage, hydroelectric power plants, hydrogen storage or oil and gas storage facilities, store electricity for several days and weeks or even years in order to compensate for seasonal fluctuations such as prolonged periods of calm wind, low water volumes or periods of little sunshine. The aim of short-term storage systems, on the other hand, is to absorb and release electricity several times within a day, even within seconds. Areas of application include grid services such as frequency containment reserve (FCR) or the temporary storage of electricity for later use during the course of a day. Storage technologies encompass again pumped hydro storage, compressed-air energy storage, flywheel energy storage and battery storage systems (BMWK 2024; 2023; Sterner & Bauer 2017). The latter battery storage systems are usually divided into three submarkets according to voltage level connection, nominal power, storage capacity and their applications. Fig. 1 provides an overview of this classification including voltage levels and areas of application: residential storage systems (see Fig. 2, also called home storage systems, typically combined with photovoltaics with a capacity of up to approximately 30 kWh), industrial storage systems (30 - 1 MWh), and large-scale storage systems (more than 1 MWh). This thesis investigates the market for residential storage systems (Figgener et al. 2020; 2021).

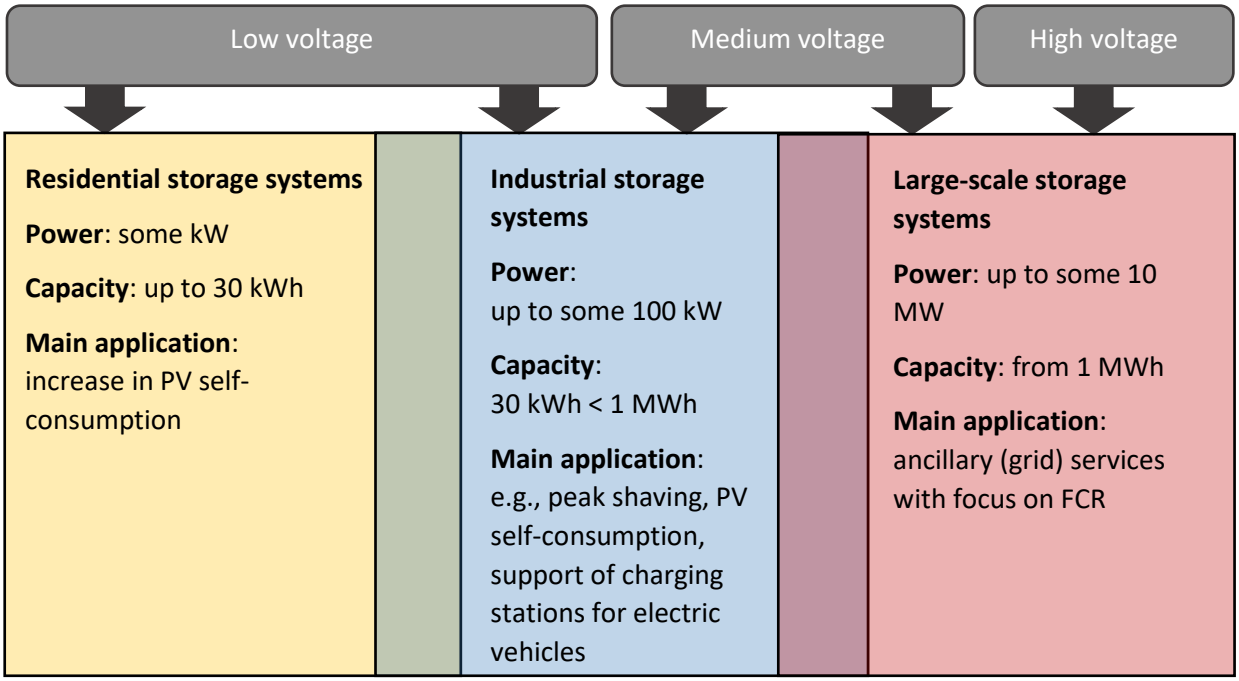


Figure 1: Overview of the different battery storage system markets and their grid connection in Germany. Source: Own illustration based on Figgener et al. (2020; 2021).



Figure 2: Selection of residential storage systems available in Germany. Source: Willuhn (2024).

In Germany, pumped hydro storage systems and battery storage (large-scale batteries and aggregated residential storage systems) are currently the most important technologies in use for short-term electricity storage (BMWK 2023). More specifically, pumped hydro storage systems are still the most relevant electricity storage technology in terms of storage capacity. However, the expansion of the installed capacity of pumped hydro storage systems is proceeding slowly. In general, their potential is limited due to the need for differences in altitude (BMWK 2023; Figgener et al. 2020). By contrast, the markets for battery storage systems show high dynamics. Especially regarding residential storage systems that are combined with photovoltaics, Germany constitutes one of the pioneering markets (BMWK 2023; Figgener et al. 2020; IRENA 2017). In this context, the high number of storage systems is related to the electricity generation from photovoltaics, which has been gaining importance in Germany since the early 1990s (Kairies et al. 2019). As mentioned in the introduction (1), in April 2024, the Federal Statistical

Office Destatis (2025) reported around 3.4 million photovoltaic systems on roofs and properties in Germany with an installed capacity of around 81.5 GW (an increase by 29.8% in the number of installed systems and a 20.5% increase in installed capacity compared to April 2023).

3.2 The market for residential storage systems in Germany

The market for residential storage systems in Germany has ever since shown high dynamics, starting as a niche market, undergoing considerable change in light of interactions with adjacent systems, and currently representing an example of a transition in its acceleration phase. In the following, I will outline this development with reference to the foci of the three articles included in this thesis.

3.2.1 An emerging market

The first industrially manufactured residential storage systems were available in Germany in 2011, for example from the companies *SolarWorld* and *Conergy*. The years 2013 and 2014 showed increasing sales figures triggered by the funding programme 275 ”Renewable Energies – Storage” launched by the German state development bank KfW. This programme supported the use of residential storage systems in conjunction with PV systems until 2018 through low-interest loans and repayment grants (Figgener et al. 2020; Kairies et al. 2019). Fig. 3 shows the high dynamics in installation figures that have reached around 1.8 million at the end of 2024 (Bundesverband Solarwirtschaft e.V. 2025).

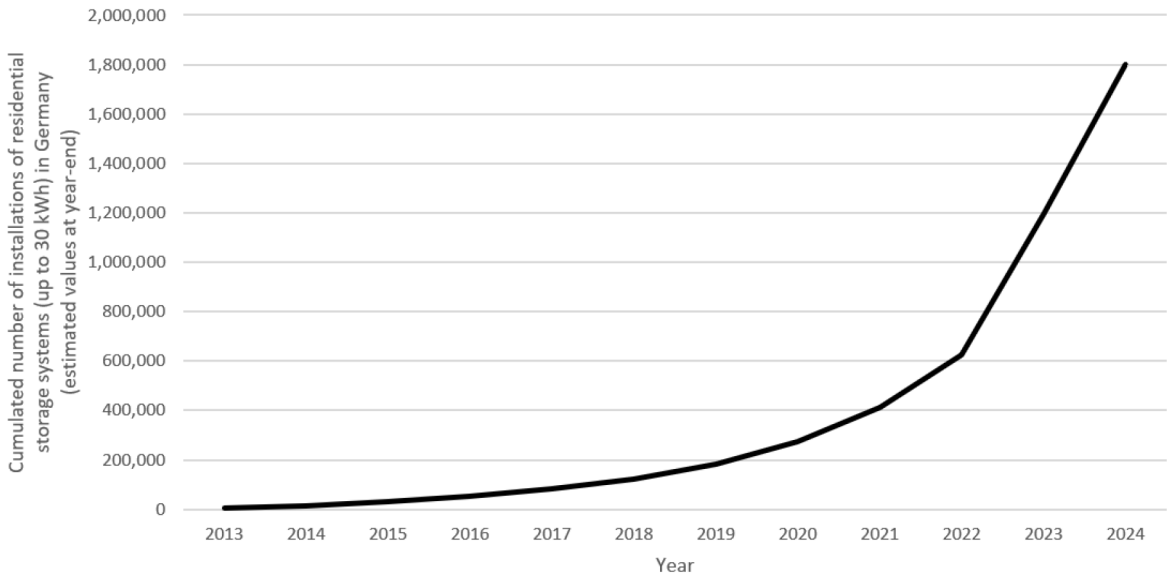


Figure 3: Cumulated number of installations of residential storage systems (up to 30 kWh) in Germany from 2013 to 2024, estimated values at year-end.
Source: Own illustration based on Bundesverband Solarwirtschaft e.V. (2025).

The market has mainly been triggered by relatively high household electricity prices and declining feed-in tariffs for electricity produced by photovoltaics, which makes self-consumption of photovoltaic power increasingly economically worthwhile. In this context, *prosuming* (i.e., *pro*ducing and con*suming* simultaneously) developed as initially (and still) most common use case (BMWK 2023; Tepe et al. 2021; Figgener et al. 2020; Kairies et al. 2019). This means that owners of PV and residential storage systems (so-called *prosumers* or *active customers*) can

store the electricity produced beyond current consumption and use it later. Hence, it becomes possible to increase the share of self-generated PV electricity among one's total electricity consumption (Zademach & Käsbohrer 2022; Figgener et al. 2020; Kairies et al. 2019). From the end customer perspective, the associated billing models are often referred to as *clouds*, since the electricity currently not needed is temporarily stored in a virtual electricity account.

Furthermore, the rapidly increasing sales of residential storage systems were favoured by significantly falling end-user prices. On the one hand, this is the result of a pronounced technological change, in the course of which lithium-ion batteries have replaced the previously common lead-acid batteries. In 2014, lead-acid batteries had a market share of around 50% in the residential storage market, whereas in the meantime, this type of battery has almost completely disappeared from the market. Lithium-ion batteries are characterised by a more compact design, longer life spans and higher energy efficiencies. On the other hand, economies of scale have resulted from the increasing importance of electric mobility and the associated global increase in production capacities for battery modules (Käsbohrer & Zademach 2021; Figgener et al. 2020; Kairies et al. 2019).

In addition to these technological developments, the market is also subject to high organisational dynamics. The central element of the newly emerging business models for residential storage systems is the above-mentioned prosuming to increase PV self-consumption. In this context, residential storage systems are usually part of energy management systems in private households (smart homes), which facilitate demand side flexibility by connecting electrical loads (storages, heat pumps, electric vehicles, etc.) and producers (typically photovoltaics). Moreover, residential storage systems have increasingly been used in so-called multi-use applications. Organised by a third-party aggregator, large numbers of digitally aggregated photovoltaic and storage systems (so-called virtual power plants) can provide frequency containment reserve. Being the fastest frequency control reserve in Germany, frequency containment reserve aims at balancing variation of grid voltage, which is possible through storing or withdrawing electricity during times of interruption or overproduction in storages (Becker et al. 2024; Figgener et al. 2020; Sousa et al. 2019). Another potential use case of such virtual power plants are *energy communities* including *energy sharing*, which enable members to sell and buy electricity from other peers depending on their current demand or surplus production (so-called energy sharing). Moreover, in the course of so-called demand-side management, such virtual power plants can take advantage of price volatility in international electricity trade through the sale of surplus energy according to price signals (Blasch et al. 2021; Sousa 2019; Mlinarič et al. 2019).

Taking part in international electricity trade, so-called third-party direct marketers (*Direktvermarkter*) can use the controllable photovoltaics and residential storage systems to mitigate critical grid conditions. The above-mentioned high number of photovoltaic systems in Germany potentially poses challenges to the electricity grids, as some of the distribution grids are not sufficiently developed to accommodate this sharp increase in decentralised electricity generation. Hence, in times of high solar irradiation and low power consumption (particularly during midday on sunny days in spring and summer), large numbers of photovoltaic installations can result in overloaded grid sections. In this context, when being controlled accordingly, residential storage systems are able to improve the grid integration of solar electricity by preventing photovoltaics from feeding in maximum electricity at midday and by facilitating the feeding in of electricity into the grid in times of low grid voltage (Figgener et al. 2020; Kairies et al. 2019). Hence, the potential benefits of residential storage systems go beyond individual savings

through self-consumption. However, as shown by Paper II and III, still only a small part of residential storage systems works in a system-integrating manner beyond mere storing of self-produced electricity for later usage.

As indicated by the dynamic business models, the provider side of these business models is heterogeneous and changing. In its initial phase, apart from *BYD*, the market was characterised by medium-sized storage manufacturers (e.g., *sonnen GmbH, SENEC GmbH, E3/DC*), who also operated as electricity suppliers. Furthermore, various smaller providers of (mostly green) electricity offered solutions involving residential storage systems. The large energy utility companies (*RWE, Vattenfall, E.ON, EnBW*) were not among the pioneers of the early days, but followed suit, e.g., with *SENEC.Cloud* from *EnBW* or *E.On Solarstrom*. The market shares of manufacturers of installed residential storage systems in Germany also reflect the changing market environment. While *sonnen GmbH, BYD and SENEC GmbH* had led the market until 2021 with similar shares (Fig. 4), *BYD* was the clear market leader in 2023 (Fig. 5).

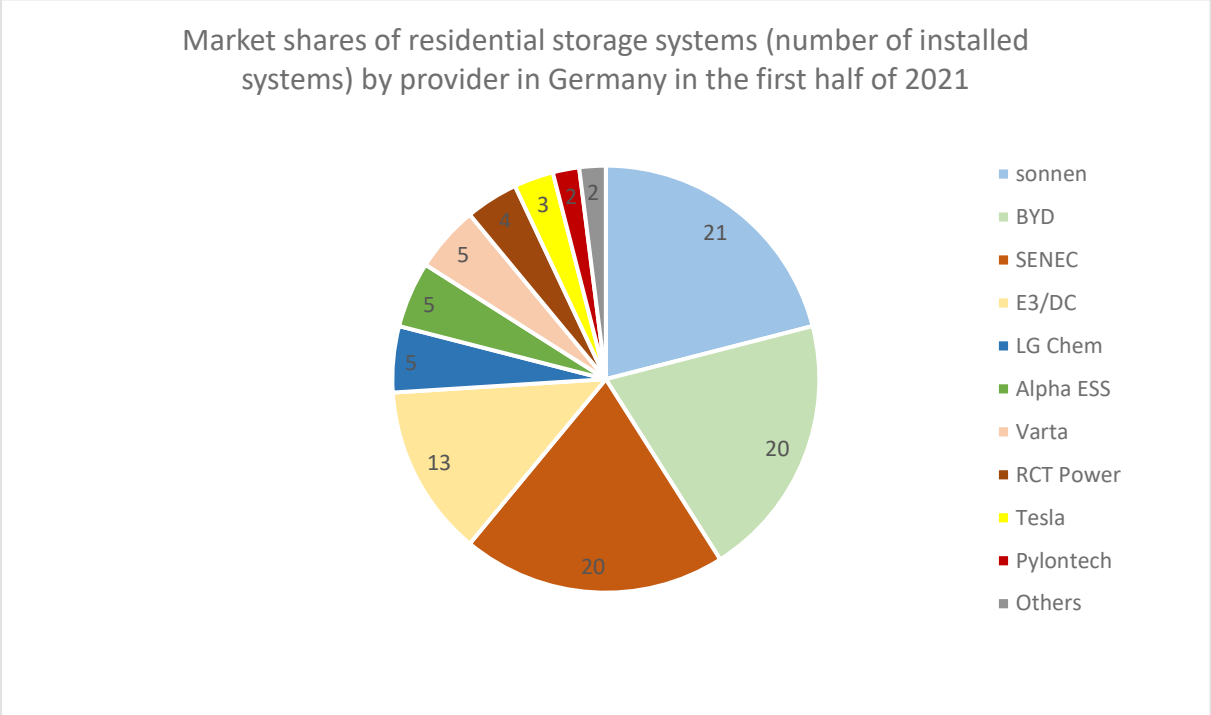


Figure 4: Market shares of residential storage systems (number of installed systems) by provider in Germany in the first half of 2021.
Source: EUPD Research in Enkhardt (2021), adapted.

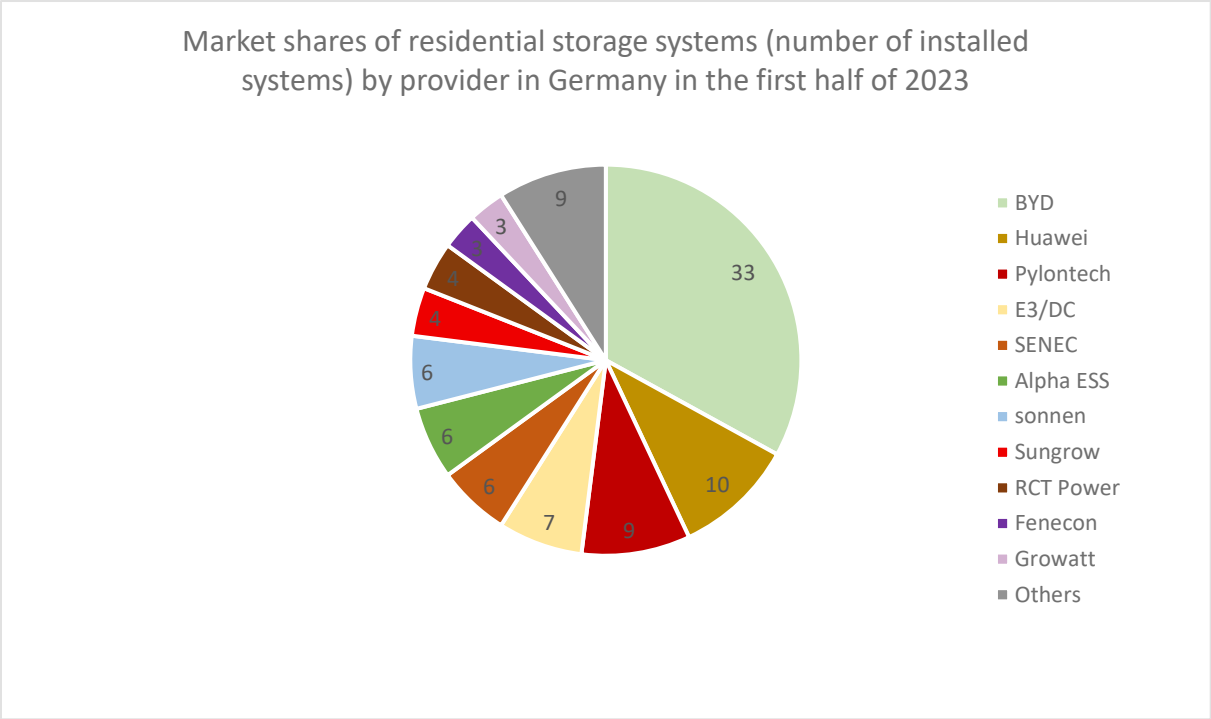


Figure 5: Market shares of residential storage systems (number of installed systems) by provider in Germany in the first half of 2023.
Source: EUPD Research (2024), adapted.

3.2.2 A market characterised by multi-system interactions

The possible applications of residential storage systems have widened in scope and have advanced into adjacent systems, in particular the mobility system. More concretely, interactions between residential storage systems and electric vehicles are observable in terms of technologies and business models (1), actors (2), and institutions (3), which is the subject of Article I of this thesis.

Similarly to residential storage systems, the market for electric and hybrid vehicles is characterised by massive rises in sales (Fig. 6). As regards technologies and business models (1), we have seen an increasing intertwining of both systems. Most importantly, batteries of electric vehicles have become integrated into full-package residential energy management systems, potentially including photovoltaics, stationary storage systems, wall boxes, energy management software and residual power contracts, which enable to charge electric vehicles with self-produced electricity (Rücker et al. 2022; Costa et al. 2022).

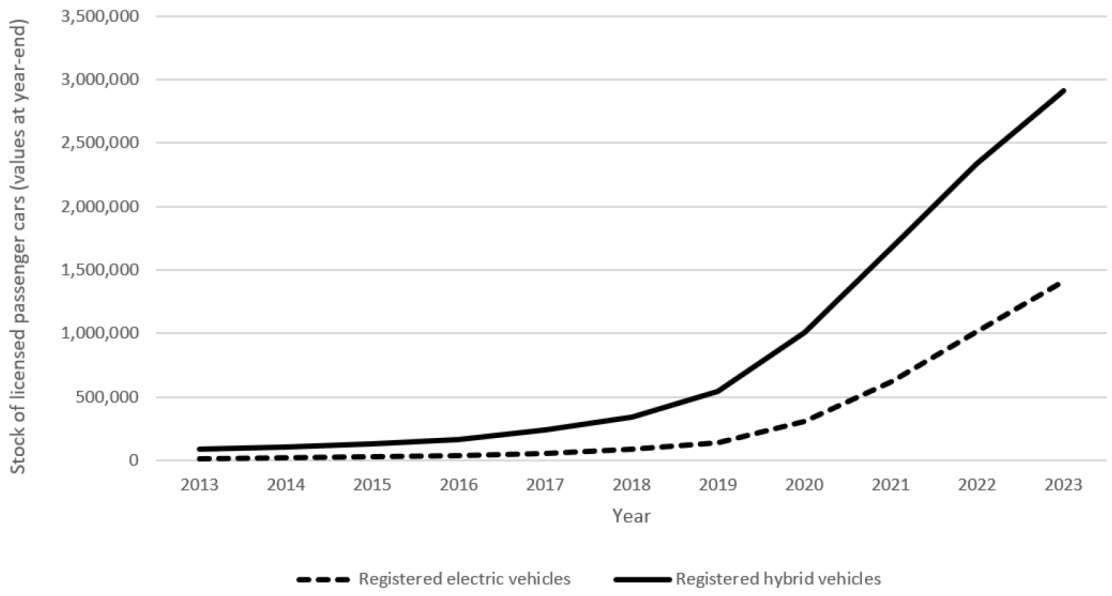


Figure 6: Stock of licensed passenger cars with electric or hybrid engines in Germany from 2013 to 2023, values at year-end. Source: Own illustration based on Kraftfahrt-Bundesamt (2025, 2023a).

On the supplier side (2), these full-package offers are often provided by collaborations of companies from both systems (e.g., *Mercedes Benz* in cooperation with *E.On*, *BMW* with *Solarwatt*, or *Tesla* with *Octopus Energy Germany*). Notwithstanding, some market players have advanced into the other system. In 2018, the *Volkswagen Group* founded its subsidiary *Elli* concerned with charging and comprehensive energy solutions, which independently provides a full-package offer including green electricity along with electric vehicles and even mere electricity contracts (*Volkswagen Naturstrom*) without an electric car (Elli 2024; Fuhs 2021). Conversely, *sonnen GmbH* has started to offer leasing agreements for electric vehicles (*sonnenDrive*). Charging tariffs regulating the contractual accounting at public charging points are offered by both electricity utilities and automotive companies (e.g., *EnBW mobility+, Mercedes Me Charge*) (Käsbohrer et al. 2024).

Industry stakeholders from both the energy and mobility sector – mostly trade associations and influential market players – come into contact due to an institutional environment spanning system boundaries (3). They negotiate potentially diverging interests in terms of standards (e.g., on the operation or the payment of public charging) or (collaboratively) engage in institutional work in order to exert influence on the regulatory environment, which needs to be adapted to technological and organisational innovations (e.g., the public infrastructure for charging electric vehicles or the enforcement of bidirectional charging). This regulatory framework is presented in chapter 3.3. Article I provides more details on regulatory barriers and institutional work carried out by actors affiliated with the electricity and automobile systems.

3.2.3 A market in its acceleration phase

In the later market stages from around 2022 on, the market for residential storage systems showed characteristics of a transition in its acceleration phase, which is elaborated on in Article III of this thesis.

The acceleration phase of transitions is characterised by challenges related to an augmented speed, scale, and scope of a transition (Rogge & Goedeking 2024; Markard et al. 2020). The market for residential storage systems serves as a telling example for studying transitions in its

acceleration phase due to several aspects: First, the German energy transition away from fossil fuels and nuclear energy towards renewables represents a very suitable example of an accelerating net-zero transition. Embedded in this, the market for residential storage systems in Germany is the largest in Europe in absolute terms of units as well as relative to population (ees Europe 2023). Second, residential storage systems represent a potential technological contribution to decarbonising the electricity system. More precisely, the technology itself constitutes a necessary complementary element for whole system change, since the further integration of renewables requires storage capacities (Markard et al. 2020; Markard & Hoffmann 2016). Third, by facilitating decentralised self-generation and self-consumption by private households, residential storage systems contribute to a changing system architecture (Wieczorek et al. 2024; Andersen et al. 2023b). Fourth, as noted above, we increasingly observe multi-system interactions with other systems, such as transport and heating, which is another significant characteristic for accelerating transitions (Andersen et al. 2023a; Löhr & Chlebna 2023; Mäkitie et al. 2022; Rosenbloom 2019). Finally, as will be shown in the next chapter, energy regulation in Germany is considered a key obstacle to a more profitable implementation of business models involving residential storage systems beyond self-consumption due to, for instance, fees and charges as well as complex metering requirements. Against this backdrop, Article III elaborates on challenges unique to the acceleration phase and the state capacity required for responding to these challenges through inducing regulatory changes.

3.3 The regulatory environment in Germany and at the EU level

As all papers are concerned with the regulatory environment of residential storage systems – focusing on multi-system interactions (Article I), taking on a scales perspective (Article II), and elaborating on required regulatory state capacities (Article III) – this section briefly introduces relevant regulation both in Germany (3.3.1 and 3.3.2) and at the EU level (3.3.3). More details can be found in the respective articles of this thesis.

3.3.1 German energy regulation: EEG and EnWG

In Germany, the Renewable Energy Act (*Erneuerbare-Energien-Gesetz,* EEG) and the Energy Industry Act (*Energiewirtschaftsgesetz*, EnWG) make up the central regulatory framework for the electricity market in general and the promotion of renewable energies in particular (Bundesministerium der Justiz 2023a, b). Most industry experts regard these acts as being the central obstacle to a more profitable implementation of the business models discussed above, i.e. the multi-use applications beyond prosuming. Especially business stakeholders, industry association representatives and lawyers specialised in energy law point to high measurement and bureaucratic requirements, a missing definition of storages or high grid fees, taxes and surcharges among other aspects (see Käsbohrer et al. 2024 for further details). Many argue that amendments required by binding EU targets (e.g., abolishing double grid fees, taxes and surcharges associated with multi-use applications) have been delayed or not implemented at the German level (Käsbohrer et al. 2024; Zademach & Käsbohrer 2021). Some emphasise that even though EU legislation might have been implemented, it is impractical due to high measurement and bureaucratic requirements along with a missing smart-meter rollout.

As highlighted in Article I, the growing interactions with the automotive industry have led to further dynamics. On the one hand, the required regulatory changes have increased in complexity, since use cases extend beyond system boundaries. On the other hand, stakeholders in the

automotive sector, such as companies and industry associations, increasingly shape public debate and take advantage of their reputation and influence on governing entities for voicing their interests in terms of regulatory changes.

3.3.2 Regulatory bodies in Germany: BMWK and BNetzA

As regards the governing dimension in Germany, the Federal Parliament holds the formal decision-making power over energy policy. Developing the corresponding legislation is mainly the responsibility of the Ministry for Economic Affairs and Climate Action (BMWK). The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railways (*Bundesnetzagentur*, BNetzA) wields considerable power over legislation despite the fact that it had been created as a downstream, executive authority, and mandated with guaranteeing the liberalisation and deregulation of the electricity market via non-discriminatory network access and efficient system charges (BNetzA 2024). Equipped with a high level of expertise and based on personal commitment, BNetzA representatives have been involved in amendments of EEG and EnWG in close collaboration with BMWK providing extensive advisory services to the ministry and even developing draft laws on their own initiative (Käsbohrer et al. 2024).

While focusing on state capacities for inducing regulatory changes, Article III reveals a changing attitude in both institutions towards residential storage systems. At the beginning of the data collection phase, rather critical opinions on residential storage systems were prevailing based on different arguments, such as difficult predictability and tractability of households using residential storage systems, or the cost of these systems. Notwithstanding, a change in attitudes and roles is observable in both regulatory bodies, triggered by the growing need of electricity storage in light of critical grid conditions and a change in the BMWK leadership due to the change of government at the end of 2021.

3.3.3 EU legislation affecting residential storage systems

As alluded to above, EU legislation plays a decisive role for the market for residential storage systems in Germany. Most importantly, EU legislation needs to be transposed into German legislation, most notably to EEG and EnWG. At the EU level, the Renewable Energy Directive (EU/2023/24133) (RED) and the Directive on common rules for the internal market for electricity (EU/2019/944), commonly referred to as Electricity Market Directive (Directive 2019/944, Directive 2018/2001), are the most relevant directives in terms of residential storage systems (European Commission 2024a, 2024b; Directive 2023/24133; Directive 2019/944). The RED and the Electricity Market Directive are concerned with rules facilitating self-consumption and energy communities claiming, for instance, a distinct legal role for energy storages and the abolishment of double fees and charges, bureaucratic barriers and inadequate measurement requirements (Directive 2023/24133; Directive 2019/944).

In Article II, EU legislation is presented in more detail. Moreover, the article sheds light on the interactions between the national and the EU scale. More specifically, the article focuses on socio-institutional rescaling, i.e. institutional work activities of actors with a stake in the market for residential storage systems who aim at fostering this technology at both scales.

4 Methodology

All articles of this thesis draw on case study research on the market for residential storage systems in Germany. Case studies investigate contemporary phenomena within their real-life context, enabling us to address 'how' and 'why' questions, usually by relying on multiple sources of evidence (Yin 2014; Eisenhardt 1989). Thus, case study research allows for generating rich explanations and contributing to theory development (Gibbert et al. 2008; Eisenhardt 1989). In this chapter, I describe and discuss my research process, the suitability of the empirical case and the research design, reflect on philosophical underpinnings of my research, and present the methods used for data gathering as well as analytical steps. Thus, I intend to make the whole research process more comprehensible and reflective than it had been possible within the context of the individual articles.

4.1 The research process

I started to empirically engage with the market for residential storage systems in Germany in 2017. At this time, this market caught Hans-Martin's and my attention due to its innovativeness – more concretely, the different co-evolving innovations (Pieroni et al. 2019; Azar & Ciabuschi 2017; Camisón & Villar-López 2014). As elaborated on above, the dynamic market for residential storage systems is characterised by technological advances in battery technology in terms of materials, life spans and capacities (Figgener et al. 2020) that are paralleled by new business models involving residential storage systems and photovoltaics, which enable users to enhance self-consumption of self-generated electricity (Tepe et al. 2021; Kairies et al. 2019). Related to this, we were further interested in corporate mergers and acquisitions and in what types of knowledge exchange is involved in these transactions.

Following advancements and processes of change in the German electricity sector by interviewing stakeholders, taking part in sector events, doing participant observation in industry associations' meetings and conducting extensive desk-based research, I noticed that sector experts describing the diffusion of this market highlight the interrelationship of business models and regulation – rather than technological advances. As mentioned above, most industry experts regard regulation as the central obstacle to a more profitable implementation of more advanced business models. Technical deficiencies were rarely mentioned in the interviews. Indeed, smart meters were criticised for some functional deficiencies, but this was also due to procedural delays in their introduction. At the same time, regulators put forward their arguments backing the current regulatory situation. Consequently, stability and change in this market can be explained by drawing on an institutional perspective rather than by focusing on technological innovation development. I empirically understood that socio-technical change is not solely about promising technological advances and their wide-reaching or transformative scope of application, but also very much about agents inducing and impeding institutional changes. Hence, I was intrigued to learn more about this contradictory situation of a dynamic market unfolding in a rather traditional or even impeding regulatory environment, which clashes with the vision of active customers contributing to the energy transition as increasingly emphasised in EU legislation.

This means that data collection and analysis was not driven by an a priori research question (Witt 2001). Instead, I began my fieldwork with a broad conceptual interest in socio-technical transitions and continued with particular attention to the institutional context of transitions.

However, this did not happen in a purely inductive sense as in research drawing on grounded theory (Corbin & Strauss 1990), but rather with being aware of commonly applied concepts in extant literature concerned with an institutional perspective on transitions (Eisenhardt 1989). This flexible research approach allowed me to investigate real-time empirical developments, for example, the change of government at the end of 2021 or the growing influence of automobile sector actors launching business models and engaging in institutional work at the interface of electricity and mobility. Taken together, the real-life peculiarities of the case itself motivated the research questions (Siggelkow 2007).

Not surprisingly, institutional change is best studied in times of institutional change (Duygan et al. 2019; 2021b). At both the German and the EU scale, my research investigates changing institutional structures. In this context, a real-time approach facilitates a rich empirical exploration of the sometimes messy conglomerate of visions, narratives and opinions associated with new technologies and business models. However, the often short-lived and diametral expectations of sector experts and far-reaching institutional changes (for instance, induced by the new government at the end of 2021) make it difficult to abstract and causally interpret the empirical material (Madsen 2022b). Against this backdrop, an iterative process of pausing my empirical work and developing a conceptual argument, which then was validated through further (follow-up) interviews, has proven to be useful. Thus, additionally fostered by the cumulative nature of this thesis, I applied a circular strategy with data analysis overlapping data collection (Eisenhardt 1989). This means that in the course of the investigation, by means of empirical work and data analysis, it became clear which further methods, questions and categories are fruitful and which interview partners can best contribute to addressing the research questions (Witt 2001).

4.2 The market for residential storage systems in Germany as an empirical case

As alluded to above, the market for residential storage systems in Germany is a telling empirical example of a socio-technical transition, as it reflects – at first glance – the traditional assumption of a niche that cumulates and scales up accompanied by niche actors challenging regime rationalities (Geels 2002; Geels & Raven 2006). Furthermore, the electricity sector constitutes a prominent and widely used empirical context for transitions research (e.g., Duygan et al. 2019; Köhler et al. 2019; Miörner & Binz 2021).

As my research progressed, I discovered that this market is much more than a 'typical' case of a niche cumulating and upscaling within the German electricity sector. Instead, it is rather a counterintuitive case in different regards (Bartunek et al. 2006). First, as shown in Article I, it was not solely niche actors driving the market in later stages, but rather incumbent players in the electricity and automotive systems such as big electricity utilities or car manufacturers. The case turned out to be an emblematic and useful example for the evolving debate on multi-system interactions (e.g., Andersen & Geels 2023; Kanger et al. 2021; Andersen & Markard 2020; Rosenbloom 2020) with automobile manufacturers advancing into the market by pursuing new types of business models and engaging in institutional work within the electricity system.

Second, this case contradicts giving ontological priority to local and national scales, what particularly applies to case studies on the energy sector (e.g., Bauer & Fünfschilling 2019; Lauber & Jacobsson 2016; Strunz 2014). Instead, the EU scale has proven highly relevant for industry stakeholders aiming at inducing institutional changes at the national scale. Hence, this case is useful for scrutinising multi-scalarity and rescaling in transitions, which is the key purpose of Article II.

Third, regulatory bodies have changed their strategies and attitude towards a largely positive opinion on residential storage systems (as highlighted by Article III), while they had proven to be rather incumbent regime actors in earlier stages of market development. This change is investigated in the context of regulatory capacities required to tackle challenges unique to the acceleration phase of transitions (Markard et al. 2020; Rogge & Goedeking 2024).

The individual papers elaborate on the suitability of the case for addressing the respective research questions in more detail.

4.3 How to approach theory development?

While aiming to explain the diffusion of new business models in the market for residential storage systems in Germany, a case study is conducted based on in-depth descriptions of "*the rich, real-world context in which the phenomena occur*" (Eisenhardt & Graebner 2007, 25) resulting from on a variety of data sources. In so doing, the objective is to make sense of observations asking if an observation is a particular case of a more general pattern (De Vaus 2001). Thus, the overall aim is to contribute to theory development in transitions research and further debates, which is addressed in the individual articles.

In conceiving a theory-developing case study design, I have been particularly inspired by the work of Eisenhardt (1989; also Eisenhardt & Graebner 2007) and Yin (2014). Furthermore, Gibbert et al. (2008) provide persuasive ideas by critically discussing Eisenhardt's and Yin's work, particularly taking account of construct, internal and external validity as well as reliability[5]. Eisenhardt's (1989) central notion is to use case studies as the basis from which to draw theory inductively, claiming independence from prior literature and past empirical observations. However, an a priori, tentative specification of constructs might be helpful, particularly regarding measuring these constructs accurately, which results in a firmer empirical grounding of emergent theory. Notwithstanding, investigators should avoid thinking about specific relations between variables and theories at the beginning of a research process. By contrast, according to Yin (2014), case study research starts by constructing some preliminary theory or theoretical propositions prior to data collection, which result from key issues in the research literature or from practical matters. This preliminary conceptualisation provides a guideline in determining the research design and eventually forms the ground for analytic generalisation. At the same time, Yin (2014) advocates some (potentially rival) theory development.

As regards the role of theory, I consider myself rather following Yin, holding a stronger dialogue between theory and empirics, but allowing for conceptual extensions to existing frameworks (Lee et al. 1999; Kuhn 1970), which is reinforced by Siggelkow (2007, 21): "*cases can also help sharpen existing theory by pointing to gaps and beginning to fill them.*" Correspondingly, according to a comprehensive research agenda for transition studies proposed by Köhler et al. (2019), integrating interdisciplinary concepts at the macro/meso/micro level into the traditional transition studies frameworks bears great potential. Taking on an institutional perspective, my research has benefitted from integrating concepts deriving from institutional theory, such as *institutional entrepreneurship* (Battilana et al. 2009; Battilana & D'Aunno 2009) and *institutional work* (Lawrence and Suddaby 2006). Drawing on the existing conceptualisation of

[5] Gibbert et al. (2008) subscribe to the positivist tradition when presenting the criteria to assess the rigour of field research, including case studies. Correspondingly, the four criteria commonly used in the positivist tradition are internal validity, construct validity, external validity, and reliability. These criteria have also been adapted for use in case studies by Yin (2014) and Eisenhardt (1989).

institutional work activities helped for a better grounding of agency and, thus, for contributing to current debates on structure and agency in transitions research. Notwithstanding, the inspiration I got from Eisenhardt has been highly valuable for developing new conceptual relationships. Retaining theoretical flexibility is important, particularly recognising that no construct is guaranteed a place in the resultant design (Eisenhardt 1989). For instance, contrary to initial considerations, the concept of *institutional navigation* (Sotarauta 2017) has not been applied in the final research design.

The dialogue with extant literature constitutes a key aspect of theory building with case studies, since any further corroboration of internal validity or generalisability through existent case studies is an important improvement in light of a limited number of cases (Baxter & Eyles 1999; Eisenhardt 1989). Therefore, in each of the individual papers, the discussion addresses similarities and contradictions of my findings in relation to current research in transition studies. Particularly conflicting findings open up the opportunity to contribute to a creative academic discussion, arguably sharpening the generalisability of findings. For instance, in Article I, the revealed relevance of discourses for institutional work contradicts Duygan's et al. (2021b; 2019) original findings stating that large financial, physical, intellectual and authoritative resources and central network positions obviate discourses. As opposed to this, I argue that contextual factors (open policy processes including public associations' hearings as well as the normative dimension and high media coverage of renewables and e-mobility in Germany) are associated with a high relevance of discourses. Thus, the juxtaposition of conflicting findings can result in a more fine-grained conceptual niveau of the current debate. On the contrary, similar findings as compared with the existing literature potentially tie together similarities of phenomena commonly not associated with each other, potentially resulting in a theory with stronger internal and external validity. For example, Article I shows that instead of initial niche players, it is rather incumbents that are capable of leveraging their resources in order to engage in institutional work. This adds the notion of multi-system interactions to recent contributions (Hellsmark & Hansen 2020; Turnheim & Sovacool 2020; Steen & Weaver 2017; Bergek et al. 2013), which argue that incumbents adopt disruptive technologies when they face political and societal pressure as well as economic incentives.

4.4 Critical realist foundations

The methodological decisions and conceptual deductions in all my papers are embedded in a metatheory dealing with ontological and epistemological issues, in other words, about the nature of reality and how we gain knowledge about it (for a comprehensive description of critical realisms see Danermark et al. 2019). My research is informed by critical realism, which traces back to Bhaskar (1978, 2008) and increasingly resonates with transition scholars (Geels 2022; Papachristos 2018; Sorrell 2018; Svensson & Nikoleris 2018).

In ontological terms, critical realism argues that reality exists independently of human consciousness and observations, in other words, the real world cannot be reduced to the empirically observable (Danermark et al. 2019; Sayer 1992). More precisely, critical realism distinguishes three domains of reality: the empirical, the actual, and the real. The empirical domain refers to events that we experience or observe. In the actual domain, events happen whether we experience them or not. Hence, the distinction between the empirical and actual domains emphasises that what happens in the world is not the same as what is observed. The real domain consists of structures and mechanisms that contribute to the production of actual events in the world. Taken

together, structures and mechanisms (the real) generate an event (the actual), which is experienced, thus, becoming an empirical fact (the empirical) (Danermark et al. 2019).

Epistemologically, critical realists consider theories as lenses or tools: *"Theory is a language, indispensable to science. […] We see and understand the world with the help of theories. Theories here serve as an interpretive framework"* (Danermark et al. 2002, 121). Thus, our knowledge of reality is theory-laden, mediated by language, concepts, and discourses, which are changing over time and across social contexts. This means that our understanding is filtered through our own and other people's previous experiences and preunderstandings. Consequently, all knowledge in fact is fallible and open to adjustment (Danermark et al. 2019; Maxwell 2012; Sayer 1992).

Based on this fundamental understanding of reality, the key task of research adopting a critical realist approach to social science is explaining social phenomena (events) by revealing the causal structures and mechanisms that produce them, as put by Danermark et al. (2019, 25): *"Scientific work is […] to investigate and identify relationships and non-relationships, respectively, between what we experience, what actually happens, and the underlying mechanisms that produce the events in the world*." Critical realism assigns causal power to both structural factors – such as societies, institutions, roles and positions as well as material structures – and human agency. Furthermore, it is argued that the events produced by structures and mechanisms are context-dependent. Thus, time and space are considered contingent conditions in the analysis of causal mechanisms (Sayer 1992).

Critical realism does not specify any particular research methods. Instead, the nature of the research object determines which research methods are suitable (Danermark et al. 2019). Sayer (e.g., in Sayer & Morgan 2022; Sayer 2000) puts emphasis on qualitative methods as they allow for explaining social structures and causal powers and for discovering actors' reasoning and circumstances in specific contexts. Arguing from a critical realist perspective, Winchester (1999, 62) considers qualitative interviews not as merely adjunct to other methods, but as *"absolutely essential"*, since non-quantifiable and non-replicable data, like experiences and attitudes, are crucial for deriving meaning and causal explanation.

4.4.1 Critical realism and socio-technical change

As mentioned above, transition scholars have increasingly payed attention to critical realism arguing that it resonates well with transition frameworks due to its focus on actors, events, causal mechanisms, and structures (Geels 2022; Papachristos 2018; Sorrell 2018; Svensson & Nikoleris 2018). Notwithstanding, Sorrell (2018) as well as Svensson and Nikoleris (2018) formulate epistemological criticism regarding the status of causal explanation in transitions research, often focusing on the MLP, and suggest stronger critical realist foundations for transition theory.

One point of criticism has been that traditional approaches in transition studies focus on superficial events instead of analysing their underlying structures and causal mechanisms. For that purpose, Sorrell (2018) as well as Svensson and Nikoleris (2018) propose an *explanatory theory* that takes account of multiple causes and distinguishes between necessary and contingent conditions as well as between structures and events. In this context, Sorrell (2018) further suggests reducing the complexity of transition frameworks and narrowing the focus. This includes simpler causal relations, validating propositions of specific concepts and using more reductionist methodologies such as agent-based and system dynamics modelling. As a further criticism,

Svensson and Nikoleris (2018) as well as Sorrell (2018) argue that the MLP accommodates agency in the form of socio-cognitive rule structures, bounded rationalities and interpretive activities and fails to account for "*actors' position in relation to systemic structures which influence their differentiated mode of access to resources and possibilities*" (Svensson and Nikoleris 2018, 466). Thereby, they emphasise the need to take consideration of material structures, such as resource distribution or ownership relations.

In response, Geels (2022) proposes an agentic-processual version of critical realism, which puts a stronger emphasis on explaining long-term transformative change, on social interactions and on process-theoretical approaches of causality and explanation. In this context, Geels (2022, 11) argues that conceptual frameworks like the MLP, TIS or SNM are epistemologically legitimate within a critical realist approach and emphasises the need for *"auxiliary theoretical modules"* for explaining particular processes and topics, such as insights from discourse theories, political science or social practice theory. This inter-disciplinary and modular strategy is reinforced by critical realist scholar Maxwell (2012, 86): *"You don't have to adopt theories as wholes; you can borrow particular ideas from different theories and use these to construct a conceptual framework that best fits your particular topic or problem."* This thesis complies with this request by integrating middle-range concepts and theories on agency like institutional work into the basic configurational frameworks consisting of actors, institutions and technologies, which is elaborated on above (chapter 4.3).

However, the articles of this thesis also address the concerns brought forward by Sorrell (2018) as well as Svensson and Nikoleris (2018) as mentioned above. Regarding the missing attention to actors' structural position and constraints, Article I explicitly accounts for enabling conditions that explain agents' ability to carry out institutional work. These enabling conditions include material structures, such as charging infrastructures for electric vehicles. In Article III, the regulatory state capacity explicitly encompasses resources, which along with abilities influence the capacities of governing entities in terms of inducing institutional changes. The structural position of actors is covered by the role of governing entities, also considering the assigned patterns of authority and mandates as well as the relationship to other organisations. How critical realism guides the argumentation of Article II is explained below.

4.4.2 Critical realism and scales

As outlined in more detail in Article II, two main perspectives on scale and rescaling are prominent in geographic theorising: the political economy perspective and post-structural approaches (Grillitsch et al. 2025; MacKinnon 2010). While the political economy perspective refers to scale as an outcome of social construction and material expression of wider social, political, economic and cultural developments (Brenner 1998; Swyngedouw 1997; Smith 1993), post-structuralist scholars understand scale as institutionalised, but always emergent sets of practices and discourses (Jones et al. 2017; MacKinnon 2010; Leitner & Miller 2007). My research is inspired by MacKinnon (2010) who aims at incorporating elements of both the political economy perspective and post-structuralism. Arguing from a critical realist perspective, MacKinnon (2010) takes account of both material and discursive dimensions when investigating how actors use scale as a dimension of strategic agency by privileging some scales over others.

The influence of a pre-existing scalar structuration is a distinguishing feature between the political economy and post-structural traditions. While post-structural approaches understand

scale as an ongoing process of becoming through the construction of social relations and identities, the political economy perspective focuses on the transformation of inherited social structures and spatial configurations as manifestations of prevailing power relations (MacKinnon 2010; Brenner 1998; Swyngedouw 1997). Informed by post-structural work on scale, MacKinnon (2010, 31) adapts this political economy scalar structural approach and argues *"that the interaction occurs between inherited scalar structures and emergent social and political projects, stressing that agency lies with the social forces advancing such projects."* Thus, in line with a critical realist conception of scale, Article II takes established scalar arrangements (e.g., the EU encompassing member states), which can be understood through socially mediated representations and discourses, as a starting point. Furthermore, MacKinnon (2010, 31) argues that in contact with inherited scalar structures, these social and political projects *"tend to privilege some inherited scales over others and reshape inherited scalar arrangements in line with their ideology and sociopolitical outlook".* Taken together, I consider the scalar arrangement as an external reality, which can be experienced through scalar narratives and discourses as well as shaped through social construction and reproduction by actors.

4.5 Methods used and empirical material

The empirical material that all papers are based on has been collected using multiple qualitative methods. Qualitative research provides rich data for studying the complex, real-world context of case studies. Therefore, case studies typically combine different data sources, such as archive material, interviews, and observations (Eisenhardt & Graebner 2007; Eisenhardt 1989). The methods and data sources of this thesis along with their validity and reliability are presented in the following chapters (documents and desk-based research in 4.5.1, participant observation in 4.5.2, and interviews in 4.5.3). The external validity of the research is strongly related to questions of sampling, which is also elaborated on in the sections on participant observation (4.5.2) and interviews (4.5.3). The last chapter 4.5.4 gives an overview of the triangulation of methods and data focusing on the internal validity of the research design.

4.5.1 Documents and desk-based research

A first source of empirical material are various types of documents concerned with residential storage systems and the German electricity sector more generally, including newspaper articles, grey literature and company websites. The latter was highly relevant for gathering knowledge on business models involving residential storage systems. Furthermore, I closely followed the developments concerning sales figures, new business models, regulatory changes and political initiatives by subscribing to newsletters from companies (e.g., *Polarstern, sonnen*) and authorities (e.g., BMWK) as well as by subscribing to online news outlets (e.g., *pv magazine, Tagesspiegel Background*). In addition, I have relied on grey literature including reports, fact sheets on battery technologies and sales figures as well as presentation slides and position papers published by industry associations, which I gained access to online through the websites of organisations and companies.

Moreover, I have drawn on regulatory documents, which mainly include legislative acts enacted by the European Union or the German government. I accessed the German legal documents via the digital legal information service *Gesetze im Internet* (translates to *Laws on the Internet*; Bundesministerium der Justiz 2024) and the database of the *Clearingstelle EEG KWKG* (a neu-

tral body for the out-of-court settlement of questions and disputes on different electricity legislation in Germany; Clearingstelle 2025a-f). EU legal documents are available via the information service *EUR-Lex* (EU 2024d) (see Tab. 2 for a full overview).

Table 2: Overview of regulatory documents from EU and the German government.

EU Directives
Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast)
Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652
Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)
Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC
German regulatory documents
Gesetz für den Ausbau erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG 2023): Erneuerbare-Energien-Gesetz vom 21. Juli 2014 (BGBl. I S. 1066), das zuletzt durch Artikel 6 des Gesetzes vom 20. Dezember 2022 (BGBl. I S. 2512) geändert worden ist
Gesetz für den Ausbau erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG 2021): Erneuerbare-Energien-Gesetz vom 21. Juli 2014 (BGBl. I S. 1066), das zuletzt durch Artikel 1 des Gesetzes vom 21. Dezember 2020 (BGBl. I S. 3138) geändert worden ist
Gesetz für den Ausbau erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG 2017): Erneuerbare-Energien-Gesetz vom 21. Juli 2014 (BGBl. I S. 1066), das durch Artikel 2 des Gesetzes vom 22. Dezember 2016 (BGBl. I S. 3106) geändert worden ist
Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz - EnWG) (Novelle 2022): Energiewirtschaftsgesetz vom 7. Juli 2005 (BGBl. I S. 1970, 3621), das zuletzt durch Artikel 5 des Gesetzes vom 20. Juli 2022 (BGBl. I S. 1325) geändert worden ist
Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz - EnWG) (Novelle 2021): Energiewirtschaftsgesetz vom 7. Juli 2005 (BGBl. I S. 1970, 3621), das zuletzt durch Artikel 2 des Gesetzes vom 21. Dezember 2020 (BGBl. I S. 3138) geändert worden ist
Gesetz über die Elektrizitäts- und Gasversorgung (Energiewirtschaftsgesetz - EnWG) (Novelle 2011): Energiewirtschaftsgesetz vom 7. Juli 2005 (BGBl. I S. 1970, 3621), das zuletzt durch Artikel 2 des Gesetzes vom 28. Juli 2011 (BGBl. I S. 1690) geändert worden ist

Sources: Clearingstelle (2025a-f); Directive (2023/24133); Directive (2019/944); Directive (2018/2001); Directive (2009/28/EC).

The legal texts were not subject to a systematic document analysis. Instead, they build the basis for developing a chronological overview of amendments in EEG and EnWG as well as for understanding the realised or missing transposition of EU legislation into German regulation. As proposed by Yin (2014), the role of documents is rather to corroborate and augment evidence from other sources. Further data sources and data collection methods are necessary, such as participant observation and semi-structured interviews, which is explained in the following.

4.5.2 Participant observation

Participant observation was mainly related to a German independent, member-based industry association for energy storage technologies. More precisely, I participated in 44 working group and two members' meetings as well as two trade fairs organised by this association (see Tab. 3). Furthermore, I took part in an online webinar of another industry association for the solar industry and two further sector-specific trade fairs (*The smarter E Europe* in June 2018 in Munich and in November 2020 as an online event). Particularly during the initial phase of the research, observing and participating in the trade fairs and industry association meetings were important first steps in gathering knowledge about the market, technical applications and business models concerning residential storage systems.

Furthermore, the participant observation helped me identify key organisations and stakeholders in the sector as a broad range of actors with various concerns and perspectives attended the events. The members of the industry association for storage technologies consist of a diverse group of public and private stakeholders across different storage technologies including national and local authorities, private organisations and companies, consultancies, law firms, and research institutions. Our professorship itself became a member in order to take part in association meetings. The industry association is organised into different working groups, which launch these regular meetings, the topics of which range from technological to market development and regulatory issues (see again Tab. 3).

Table 3: Overview of working group and members' meetings as well as trade fairs organised by a German industry association for energy storage technologies, participant observation.

No.	Topic	Date
1	Energy law working group	Sep 2020
2	Energy politics working group	Sep 2020
3	Task force for EEG amendment	Sep 2020
4	Energy politics working group (presentation by member of EU parliament)	Sep 2020
5	Working group on residential storage systems	Oct 2020
6	Finance and Investments working group	Oct 2020
7	Workshop: Residential storage systems	Nov 2020
8	Storage technologies working group	Nov 2020
9	Standards and quality criteria working group	Nov 2020
10	Trade fair on battery storage systems	Nov 2020
11	Members' meeting	Nov 2020
12	Energy law working group	Dec 2020
13	Working group on residential storage systems	Dec 2020
14	Task Force for EnWG amendment	Jan 2021
15	Energy law working group	Feb 2021
16	Working group on residential storage systems	Feb 2021
17	Trade fair on residential and industry storage systems	Mar 2021
18	International market development working group	Mar 2021
19	Energy law working group	Apr 2021
20	Energy politics working group	Apr 2021
21	International market development working group	Apr 2021
22	Workshop: Storage systems and manufacturing industry	Apr 2021
23	Storage technologies working group	May 2021

No.	Topic	Date
24	Energy law working group	May 2021
25	Working group on residential storage systems	June 2021
26	Task force Smart Meter Gateway	July 2021
27	Energy politics working group	Sep 2021
28	Energy law working group	Oct 2021
29	Energy law working group	Nov 2021
30	Members' meeting	Nov 2021
31	Storage technologies working group	Feb 2022
32	Energy law working group	Feb 2022
33	Energy law working group	Apr 2022
34	Working group on residential storage systems	May 2022
35	Workshop: Regulation of fast charging	June 2022
36	Energy law working group	Sep 2022
37	Storage technologies working group	Sep 2022
38	Working group on residential storage systems	Sep 2022
39	Mobility working group	Sep 2022
40	Task force on §14a EnWG	Oct 2022
41	Energy law working group	Nov 2022
42	Task force residential storage systems	Jan 2023
43	Working group on residential storage systems	Feb 2023
44	Mobility working group	Feb 2023
45	Energy law working group	Apr 2023
46	Mobility working group	Apr 2023

Source: Author's compilation.

Especially regulatory issues were a heatedly discussed topic in many meetings, mainly launched by the working groups on energy law and energy politics as well as the task forces created specifically for amendments of central regulation. Besides representatives of the industry associations themselves, the members of these working groups and task forces were mainly representatives of law firms, consultancies, authorities and private companies. The meetings usually took one to three hours and consisted of presentations of regulatory amendments, discussions of the consequences for members' business models and drafting of the further steps of the association's advocacy work (such as position papers). So to speak, I have been in the 'machine room' of institutional work. Thus, observing the industry associations was an important factor making me adopt an institutional perspective.

In 2018, I attended the trade fair *The smarter E Europe* in Munich. This trade fair allowed for informal conversations and reflections with sector experts during lunch and coffee breaks as well as ad-hoc interviews and observing other stakeholders exchanging knowledge at this very specific temporary event (Glückler & Panitz 2015). Due to the COVID-19 pandemic, however, all further observed meetings (trade fairs, members' meetings, working group meetings) moved online. Consequently, I was not able to continue the more natural and spontaneous interactions with other participants. The online meetings were, however, easily accessible, allowed me to stay updated on regulatory developments in the sector more easily and provided a very comprehensive account of the work of industry associations in the energy sector.

The gathered material is composed of extensive notes, but also presentation slides and participant lists. Since especially in large meetings the other participants were not personally informed

of my presence as a researcher in advance (however, the industry association as a whole was), I decided not to directly quote them in my work. Instead, I asked the respective participants for an interview in case their perspectives seemed relevant to me, or I searched for publicly available material issued by them or by their organisation or company. In general, I have tried not to 'manipulate' these events, for instance, by asking questions (Yin 2014), in order for the empirics to be as authentic as possible.

When it comes to the validity of participant observation, field data are commonly regarded as being closely tied to empirical observation and, thus, contributing to an internally valid research design. More concretely, data derived from participant observation result from a less artifactual situation than other methods. The observed people are more likely to act as they would have in the absence of the researcher (Yin 2014; Emerson 1981). From my experience, this especially comes to bear in online meetings. Furthermore, due to the relatively large number of observed meetings, the findings could recurrently be revised and tested. Concerning external validity, the question arises whether the industry association's meetings represent the typical work of associations in the electricity sector in general. In my case, this question is rather difficult to answer by comparing meetings of different associations (I participated in only one meeting of another association), but was instead addressed by means of interviews, since many participants hold memberships in various associations. As to that, interviewees confirmed that the work of the industry association I mainly observed is very similar to others. Besides, taking impressions and findings back to the field in this way reveals the diversity and depth of participants' understandings of the events and contributes to the validity of the data collection method (Flick 1995; Emerson 1981). As claimed by Baxter and Eyles (1999), this kind of data check can be done by those researched and, hence, beyond the scientific community, for fostering consistency and adequacy of data-to-concepts links without being biased by academic discourses.

The construct validity of this data is closely related to the specific research questions of the individual articles (De Vaus 2001). Essentially, I consider observing industry associations as very relevant for investigating agency in the electricity sector, especially concerning the notion of institutional work. The relative relevance of industry associations and the outcome of their institutional work have been revised by interview statements (see chapter 4.5.3). Reliability is mainly ensured by the fact that the observed participants do not consider the observer significantly constraining their actions, and that data are obtained by observing group interaction rather than the researcher interacting with observed actors (Emerson 1981). In my view, both aspects apply to my fieldwork.

4.5.3 Semi-structured interviews

A final source of empirical data are semi-structured in-depth interviews. I conducted 49 interviews from February 2021 until September 2024 with diverse stakeholders from the German energy and automobile sectors as well as EU level actors, including politicians, civil servants, researchers, NGOs, municipal organisations and private sector representatives (see detailed list in Tab. 4). Interviews are the commonly applied method in case study research (Yin 2014). The conversational nature of the semi-structured interviews prompted interviewees to describe their perspectives on the market and its institutional context in detail, while also allowing for opportunities to talk about unanticipated topics coming up during the interviews (Schoenberger 1991).

Table 4: Overview of semi-structured interviews conducted throughout the project.

No.	Interviewee	Date
1	Industry association representative (energy sector)	Feb 2021
2	Company for energy management systems, telecommunications: CSO, Consultant	Feb 2021
3	Chamber of Commerce and Industry representative	Feb 2021
4	Private research institute representative	Feb 2021
5	Company for energy management systems, storage systems: Head of business development	Mar 2021
6	Private research institute: Executive director	Mar 2021
7	Storage manufacturer representative: In-house lawyer	Mar 2021
8	Energy utility representative: Product manager	Apr 2021
9	Law firm for energy law: Lawyer	May 2021
10	Energy utility representative	May 2021
11	Energy utility representative: In-house lawyer	May 2021
12	Law firm for energy law: Lawyer	May 2021
13	Distribution grid operator representative	May 2021
14	Federal Network Agency representative	June 2021
15	Industry association representative (electrical industry)	June 2021
16	Industry association representative (electrical industry)	June 2021
17	State Network Agency representative	July 2021
18	Researcher (E-mobility)	July 2021
19	Municipal grid operator representative	July 2021
20	Federal Ministry for Economic Affairs and Climate Action: Civil servant	July 2021
21	State Network Agency representative	July 2021
22	Transmission grid operator representative	Sep 2021
23	Researcher (energy sector)	May 2022
24	Storage manufacturer representative: In-house lawyer (follow-up)	July 2022
25	Energy utility: In-house lawyer (follow-up)	July 2022
26	Industry association executive director (E-mobility)	Sep 2022
27	Industry association executive director (energy sector)	Sep 2022
28	Industry association representative (automotive industry)	Sep 2022
29	Automotive supplier representative	Jan 2023
30	Storage manufacturer representative: Expert for e-mobility and energy management systems	Mar 2023
31	Storage manufacturer representative: CEO	Apr 2023
32	Accredited Parliamentary Assistant at the European Parliament	Apr 2023
33	Energy utility: Representative at EU level	Apr 2023
34	Representative of EU-level industry association (energy sector); former representative of EU-level consultancy	Apr 2023
35	Representative of EU-level industry association (energy sector)	Apr 2023
36	Representative of EU-level industry association (energy sector)	Apr 2023
37	Representative of EU-level industry association (energy sector)	Apr 2023
38	Industry association representative (energy sector)	May 2023
39	Representative of EU-level NGO (standardisation)	June 2023
40	Representative of EU-level NGO (environment, sustainability)	July 2023
41	Representative of EU-level consultancy	Aug 2023

No.	Interviewee	Date
42	Federal Ministry for Economic Affairs and Climate Action: Civil servant	Nov 2023
43	EU Commission Directorate-General Energy	Nov 2023
44	Federal Ministry for Economic Affairs and Climate Action: Civil servant	May 2024
45	Industry association executive director (energy sector) (follow-up)	May 2024
46	Federal Ministry for Economic Affairs and Climate Action: Civil servant	June 2024
47	Consulting agency on e-mobility and charging (on behalf of the Federal Government)	June 2024
48	State Network Agency representative	Aug 2024
49	Federal Network Agency representative (follow-up)	Sep 2024

Source: Author's compilation.

Relating to the suitability of especially corporate interviews as a data collection method, Schoenberger (1991) provides valuable reference points. She emphasises the worth of corporate interviews in capturing the rationales underlying strategic decisions and in considering the firm as an institutional agent embedded in constraining and enabling internal and external networks. Furthermore, qualitative interviews are particularly helpful for inductive reasoning especially in times of economic and social change (e.g., due to the diffusion of new technologies), when analytical categories and theoretical principles underlying much quantitative research are challenged. This holds true for this case study. Winchester (1999) highlights the role of qualitative interviews in critical realist frameworks, since interviews aim at understanding underlying structures, meanings, discourses, and causal mechanisms of social processes underpinning observable behaviour (as elaborated on in chapter 4.4). In the context of critical realism, non-quantifiable and non-replicable data, like experiences and attitudes, can be analysed in a holistic sense for deriving meaning and causal explanation. This particularly comes to bear in Article II, where past experiences and the perception of future opportunities constitute explaining factors for agency.

I identified relevant interview partners through desk-based research and during participant observation, but also through the snowball method, i.e. interviewees were asked to recommend further potentially relevant persons (Lewis-Beck et al. 2004). As regards deciding on relevant interviewees, research aiming on theory development by conducting case studies usually relies on a theoretical sampling, i.e. theoretically useful cases replicating or extending theory by filling conceptual categories (Yin 2014; Eisenhardt 1989). When entering the field, I rather followed a purpose sampling strategy, where interviewees are selected based on who is likely to provide detailed empirical data relevant to the research questions (Kuckartz 2014; Baxter & Eyles 1999, a theoretical sampling was applied later on as mentioned below). I was targeting individuals representing key organisations and stakeholders in the German electricity sector, who I expected to possess specialist knowledge on and experience regarding the development of the market for residential storage systems in general and the role of electricity regulation in Germany in particular. I aimed at including different perspectives by interviewing persons promoting residential storage systems, actors rather sceptical about their diffusion as well as rather outside observers possessing knowledge of the market in order to limit bias concerning the normative attitudes towards the benefits and disadvantages of residential storage systems (Eisenhardt & Graebner 2007). Especially providers of business models involving residential storage systems tend to appear quite persuasive in emphasising the high potential of the technology, which is unjustifiably hampered by regulation. In this vein, conducting participant observation in an association obviously advocating residential storage systems entails the risk of identifying

with the study group and becoming a supporter of the arguments brought forward by them (Yin 2014; Baxter & Eyles 1999). Consequently, an interview sampling strategy covering different perspectives is of particularly high relevance.

In the course of maturing paper ideas, the range of potential interview partners developed and narrowed corresponding to the specific topics of the papers, i.e. actors from both the electricity and automobile sectors engaged in or having expert knowledge on institutional work at the interface of both industries for Article I, interviewees embedded in the EU scale or in both the national and the EU scale for Article II, and further interviews with regulatory bodies in Germany for Article III. Consequently, each of the individual papers draws on a specific sampling. At this point, in order to conceptualise extensions to existing theory, the sampling strategy turned to a theoretical sampling. I deliberately chose interviewees to replicate specific categories, which were expected to be of conceptual interest based on previous empirical work (Yin 2014; Eisenhardt & Graebner 2007; Eisenhardt 1989). For instance, I sampled different actor groups[6] (e.g., NGOs vs. private sectors actors vs. industry associations, or big electricity provider vs. SME storage manufacturer) and variations in scale-embeddedness (national vs. EU vs. embedded in both). In addition, I aimed at including polar types (Eisenhardt & Graebner 2007; Eisenhardt 1989), for instance, by addressing big electricity providers or industry associations well-known for extensive institutional work. This also includes 'negative cases', i.e. I got back to interview partners who first refused to do an interview due to not being engaged in institutional work and asked them once again about the reasons for not being engaged in institutional work, such as experiences or perceived opportunities.

Regarding the impact of the sampling on the external validity of the research design, controlling extraneous variation of theoretical categories is crucial for defining the limits to the generalisability of the findings (Eisenhardt 1989). For instance, a specific sampling allows for extending the knowledge on institutional work to a broad range of actor types, their sector affiliation or scale-specific embeddedness. In this context, the external validity is highly dependent on the specific research questions of the individual articles. Industry-level characteristics (e.g., residential storage systems being an end-user market, having open policy processes including associations' hearings, or being normatively oriented) can be taken into account through a dialogue with the extant literature (as described in chapter 4.3).

The sampling also affects the internal validity of the research design. More concretely, the sampling strategy aims at revealing and ruling out alternative explanations for the findings (Eisenhardt & Graebner 2007; Eisenhardt 1989). For instance, the change of German government at the end of 2021 rivalled institutional work as an explaining factor for institutional changes. Hence, I sampled representatives of ministries and governmental agencies to take account of the relationship between the changing government and amended regulation. Article III focuses on the role of regulatory agencies revealing in more detail the impact of the newly introduced government. More fundamentally, regarding both the purposive and theoretical sampling strategies, the selection of interview partners resulted from my subjective perception of the relevance of individuals as well as the subjective recommendations by interviewees through the

[6] It should be noted that I could not conduct any interviews with the big German car manufacturers, which represents a limitation of this work. All of my interview requests were rejected, citing time constraints and reduced capacities due to crisis management (related to Covid-19 and the energy crisis). In response, I relied on the assessments of other interviewees, in particular representatives of industry associations that represent the interests of the big car manufacturers.

snowball method. This might also constitute a source of potential self-selection bias in the material and a challenge to the validity of the research (Kuckartz 2014; Baxter & Eyles 1999). One way to reduce this risk is to triangulate methods and data sources, which this project aimed to do. The effects of triangulating the different data sources and data collection methods on the validity of the entire research design will be elaborated on in chapter 4.5.4.

In order to ensure reliability, the list of interview partners (see again Tab. 4) and the interview guides are presented in this thesis (Gibbert et al. 2008; see Appendix B). The validity of the data collection method was addressed by getting informed about the respective firm (or association, NGO etc.) in advance. As stated by Schoenberger (1991), a well-informed interviewer is more likely to evoke more engaged and thoughtful responses. In some cases, it was possible to check the consistency and verifiability of statements by interviewing more than one person within one organisation, thereby also mitigating impression management of image-conscious interviewees (Eisenhardt & Graebner 2007). Regarding two organisations sampled for Article II, I interviewed two representatives of the same organisation, but on different scales (one national and one EU representative). In general, I always asked for the specific position and main tasks as well as preceding ones within this or other organisations in order to better assess the relevance interview give to certain aspects. Further verification strategies were asking counterfactual questions, thus, requiring the interviewee to construct a consistent argument (e.g., questions about the diffusion of the market given a counterfactual regulatory environment) (Svensson & Nikoleris 2018), checking potential ambiguities concerning the understanding of questions or interpretation of terms and categories during the interview, combining open and specific questions, and inviting the interviewees to compare their organisation to others in the same industry (which they potentially also had worked in) and explain the differences (Schoenberger 1991).

I reached out to the interviewees via email, also introducing my research in general, the purpose of the specific interview as well as the key issues I was planning to talk about. I always offered to send interview questions beforehand, which almost two thirds of the interviewees made use of. As alluded to above, I developed individual interview guides. In general, my understanding of the market and the research focus developed throughout the project, which is reflected in the interview guides (Helfferich 2011; Gläser & Laudel 2010; see again Appendix B for interview guides used for rather initial scoping interviews and related to the different papers). In total, I carried out 49 interviews. Three interviews were accompanied by my supervisor Hans-Martin Zademach, while I was acting as the principal interviewer. One interview was conducted face-to-face, six over the phone, and the remaining 42 via videoconferencing. The use of remote interviewing was in the first place a result of lockdowns and travel restrictions during the COVID-19 pandemic but has proven useful in terms of time investment and travelling expenses more generally, especially considering the focus on EU institutions in Article II.

A potential disadvantage of remote interviewing lies in the access to high-speed internet or in the lack of familiarity with videoconferencing software (Hall et al. 2021). However, I do not expect this to be the case in the German setting, and especially not among my potential interviewees, most of which are working at institutions that make regular use of this type of technology, particularly during and in the aftermath of the pandemic. A further problem might be the question whether or not videoconferencing and interviewing over the phone impedes rapport between the researchers and the participants, which is a controversially discussed issue. While some scholars consider interviewees to be more comfortable in their own surroundings and emphasise the establishment of rapport in online interviewing, others report on interviewees

preferring face-to-face contexts to build rapport or caution that remote interviewing may restrict the depth of interaction and rather leads to participant fatigue (Keen et al. 2022; Hall et al. 2021). For my part, I have been very satisfied with how remote interviewing worked. Of course, I felt better rapport with some interview partners than with others, but I do not consider remote interviewing the decisive factor.

The rapport between interviewees and the researcher leads on to reflect on how knowledge creation is influenced by this social relation. Beyond the ability to develop rapport, power relations, age, gender, ethnicity and other outward appearances may potentially affect the reactions of respondents (Baxter & Eyles 1999). However, concerning the interviews conducted in this project, I do not consider power relations between interviewer and interviewees to be of relevant influence on the data gathered. Furthermore, I did not feel a great discrepancy between the interviewees and me in terms of socio-economic characteristics (e.g., education level), which might have affected the respondents' attitudes or behaviour. Taken together, I felt to be on par with my interviewees.

I started all interviews by introducing myself as well as elaborating on the purpose of the interview and the research project in general. Furthermore, I asked for permission to record the interviews. All but seven interviews have been recorded. Moreover, I asked the interviewees for permission to quote their statements directly. Relating to that, but also out of interest, some interviewees requested to see the manuscript prior to its publication, which I shared in those cases. I explained that quotes would be associated with a generic identifier (e.g., electricity supplier representative) instead of names of individuals or organisations.

The interviews lasted between 20 and 124 minutes, taking about one hour on average. They were conducted in German or English (particularly the ones carried out with EU-level actors in the context of Article II). All but eight interviews were subsequently transcribed (mostly verbatim) using the software MaxQDA and partially relying on the help of a student assistant. When quoting from the interviews, I translated the corresponding German passages in the transcripts to English. Parallel to data collection, I compiled thematically organised summaries of the interviews, which constituted a first attempt of linking empirical fieldwork data back to my conceptual considerations. Regarding data analysis, I coded the interview material multiple times (first more openly, subsequently more focused, Flick 1995, see chapter 4.6), according to research foci and codes at the respective stage of the research project. The methods sections of the individual papers provide a more detailed account of how the material was organised and analysed in relation to the respective research questions.

As discussed with respect to the sampling of interview partners, the purpose and focus of the interviews have changed over the course of the research. The first five interviews were of a rather explorative nature focusing on more general questions, for example, the scope of technological and organisational innovations, perceived sector-specific contestations and challenges, actor alliances as well as EU legislation and its role in the German regulatory context. At a later stage, resulting from my empirical observations, I carried out interviews focusing on the increasing interface of the electricity and automobile systems in light of the electrification of individual transport. I included stakeholder representatives from the automotive industry, such as industry associations, supplier firms, and researchers. Here, I aimed at deepening my understanding of institutional work activities carried out by agents affiliated with different sectors, which is the key focus of Article I. Later on, I accomplished a further round of interviews, which focused specifically on the rescaling of institutional rationales at different scales, in my case at the German and the EU level, which is the key empirical focus of Article II. Hence,

these interviews included topics such as perceptions and experiences regarding institutional work across scales, actor alliances as well as the scalar conditions for and motivations of institutional work to induce institutional changes. For this purpose, I also targeted EU level agents (NGOs, EU institutions, industry associations). The latest interviews were related to Article III shifting back to the national level and shedding light on regulatory bodies in Germany. The key themes covered acceleration challenges of transitions, their regulatory implications and the capacity needed to induce corresponding institutional changes.

4.5.4 Triangulating methods and data sources

The use of multiple sources of evidence is a commonly chosen way to strengthen the credibility of findings in case studies and is referred to as triangulation (Yin 2014; Eisenhardt & Graebner 2007; Eisenhardt 1989). This is also pursued by this study. The chapters presenting both methods applied, participant observation (chapter 4.5.2) and interviews (chapter 4.5.3), take account of their measurement validity and reliability as well as their influence on the internal and external validity of the entire research design. The aim of this chapter is to discuss, in short, how the combination of multiple data sources and methods affects the whole research design.

Triangulation is defined as the combination of methodologies while studying the same phenomenon (Jick 1979). More concretely, triangulation can refer to the triangulation of multiple data sources, methods, investigators and theories (Yin 2014; Baxter & Eyles 1999). One aim of triangulating is to foster the reliability and validity of the data collected in case of congruent results. Another purpose is to capture a more complete, holistic, and contextual portrayal of the object of investigation, since the use of multiple measures may also uncover variance of data, which otherwise may have been neglected (Baxter & Eyles 1999; Jick 1979). This case study triangulates data and methods pursuing both objectives.

The often implicit (as regards multi-case studies maybe obvious) triangulation of data sources refers to the use of multiple sources of evidence also within a method, for instance, the use of quotations from different respondents. Converging evidence strengthens the construct validity of the results, since the multiple data sources provide multiple measures of the same phenomenon (Yin 2014; Gibbert et al. 2008; Leonard-Barton 1990; Eisenhardt 1989). Within both participant observation and the semi-structured interviews, I gathered material from different sources to study the same phenomenon through different data. That means, for instance, different interviews and association meetings covered the same topics. In this context, congruent findings encouraged the confidence in the research design investigating what it claims to investigate.

Triangulation of methods is useful in the validation process, since congruent results from using two different methods enhances the confidence in the construct and internal validity of the case study. Concerning the internal validity of a research design, alternative theoretical explanations or technical and methodological disruptive factors can undermine the conclusions drawn from the research. Multiple methods, however, can rule out especially such methodological rivals in order to answer the research questions as unambiguously as possible (Gibbert et al. 2008; Siggelkow 2007; De Vaus 2001; Eisenhardt 1989; Jick 1979). Moreover, reconciling dissimilar results affords the opportunity to enrich explanation (e.g., discovering unseen contextual factors) (Gibbert et al. 2008; Jick 1979). However, the effectiveness of a triangulation of methods is based on the premise that the weaknesses of one method will be counterbalanced by the strengths of the other (Flick 1995; Jick 1979).

As regards triangulating methods in this study, agency has been captured by conducting interviews, participant observation and taking account of the outcome of agency in the form of institutional changes (albeit without claiming direct causality). In some regards, both methods are complementary in the sense that they compensate for methodological biases of the other. While participant observation outweighs the strong influence of the researcher on interviews, the impression management of interviewees (though this may also happen in association meetings) as well as interviewees' retrospective sense-making due to the real-time character of participant observation (Eisenhardt & Graebner 2007; Leonard-Barton 1990), interviews allow for controlling the sampling and the issues covered. Voices being rather sceptical about residential storage systems and the agency of NGOs, for instance, could become marginalised only studying industry associations.

In terms of construct validity, interview statements on the relevance of industry associations for inducing institutional changes have reinforced the suitability of participant observation of industry associations for investigating agency. However, direct causality between institutional work and institutional changes is difficult to prove as the agents having been lobbied by industry associations are not necessarily always the ones eventually initiating institutional changes. In this regard, in the sense of alternative theoretical explanations, Article III focuses on regulatory bodies and argues that – apart from institutional work carried out by industry stakeholders – other factors, such as a change in government or critical grid conditions, may lead to a shift in regulators' attitudes and eventually institutional changes. With respect to capturing a holistic picture of agency by applying multiple methods, participating in association meetings has proven particularly useful for revealing the collective character of institutional work (e.g., considering the institutional work practices *political advocacy* or *constructing normative networks*).

4.6 Conducting a qualitative content analysis

The data gathered in the course of the research project was subject to a qualitative content analysis (Mayring & Fenzl 2019). Mayring's approach to qualitative content analysis fits the aim of the research design as it follows a category system claiming theory-guided investigation, while it also allows for openness to inductively generate categories. Thus, qualitative content analysis is suitable when starting from theory, but at the same time aiming to develop conceptual extensions. Despite this openness, qualitative content analysis is methodologically controlled through a category system, which brings about its strong ability to deal with complex empirical data (Kohlbacher 2006).

The empirical material was collected throughout most of my research project, which resulted in a continuous analysis and a constantly improving understanding of the case. As discussed above in the section on theory development (4.3), I started with some a priori propositions and concepts. I put these into dialogue with empirics in order to identify connections as well as tensions and, thus, further avenues for exploration. These reflections were turned into analytical codes, which were then used to organise the empirical material (field notes and interview transcripts).

In this context, a replication logic has been applied (Yin 2014; Gibbert et al. 2008; Eisenhardt & Graebner 2007; Eisenhardt 1989). This means that cross-case comparisons were made by selecting categories and dimensions and then looking for similarities and differences within and

across groups, such as actor types (e.g., industry associations, electricity utilities). Thus, it becomes possible to reveal patterns of within-group similarities and intergroup differences. The resulting patterns eventually led to tentative themes, concepts, and relationships between variables or a conceptual framework, which underwent an iterative process of comparing emerging theory with data until theoretical saturation was reached. This fits case study research, as Eisenhardt (1989, 541) states: *"The central idea is that researchers constantly compare theory and data—iterating toward a theory which closely fits the data."*

I used the MaxQDA software for coding, which has proven useful for organising within-case and cross-case patterns at the same time (Rädiker & Kuckartz 2019). Inter-coder reliability is maintained by documenting category definitions, key examples and rules for coding. In order to respond to the potential problem of drawing conclusions based on mere text excerpts (Kohlbacher 2006), I always took account of within-case patterns, i.e. the whole story of a specific case (Eisenhardt 1989). Finally, the coded material has been reduced, paraphrased and abstracted in such a way as to preserve the essential content.

PART 2: Articles submitted

5 **Article I:** Multi-system interactions and institutional work: Actor interactions at the interface of residential storage systems and electric vehicles in Germany[7,8]

Abstract: Multi-system interactions are receiving increasing attention within transition research. However, understanding the consequences of increasing couplings between adjacent systems for transitions requires further research. In response, this paper applies the concept of institutional work to understand the role of actors creating institutional couplings for the reconfiguration of multiple systems. We further elaborate on enabling conditions for institutional work from a sectorsensitive perspective. In-depth interviews with energy and automobile sector experts and participant observation at industry association events show that cross-sectoral networks and advocacy are important mechanisms for creating regulative couplings. However, particularly actors in the automotive industry are able to advance into the electricity market due to increasing access to political institutions and enhanced intellectual and physical-material resources. Thus, we show how within-system incumbents leverage their resources and engage in cross-sectoral institutional work in order to gain knowledge and integrate new technologies.

5.1 Introduction

Research on sustainability transitions deals with the question of how the rigidities and path-dependencies of existing system structures are overcome towards new, more sustainable modes of consumption and production (Markard et al., 2012; Geels, 2002). These changes are traditionally conceptualized as single-sector phenomena, particularly in infrastructure sectors, since these sectors are highly institutionalized constellations of user practices, technologies, regulations and professional standards reflecting a high degree of path dependence, few technological opportunities and high entry barriers (Köhler et al., 2019; Jensen et al., 2016; Raven et al., 2016).

However, recent contributions have increasingly criticized transition studies for limiting analysis to isolated sectors (Andersen and Geels, 2023; Kanger et al., 2021; Andersen and Markard, 2020; Rosenbloom, 2020). Instead, transition pathways require interactions between multiple systems in terms of actors, institutions and technologies, such as complementary technological innovations, cross-sectoral business models or overarching policy and planning processes. This applies to decarbonization pathways considering, for instance, the electrification of transport or the fields of heat and power (Löhr and Chlebna, 2023; Rosenbloom, 2019). Thus, it is crucial to understand how changes in connected systems can stimulate or hinder systemic shifts.

This paper seeks to contribute to this debate by focusing on how the reconfiguration of multiple systems is shaped by actors creating institutional couplings. Reinforcing the relationship of

[7] Articles I, II, and III were adopted nearly unchanged from the versions published in or submitted to Elsevier. Only the figure and table captions as well as cross-references to other chapters in the text were adjusted, appendices were placed at the end of this thesis and renumbered correspondingly. Furthermore, some additional references and footnotes were added as well as minor typing errors were corrected.

[8] The article was published in the Journal *Environmental Innovation and Societal Transitions* in April 2024. This multi-disciplinary journal publishes studies of innovations and socio-economic transitions, especially related to fossil energy use and climate change (Elsevier 2025a). Thus, this text is the published version. The article has been co-authored by Teis Hansen, University of Copenhagen, Denmark, and Hans-Martin Zademach, Catholic University of Eichstätt-Ingolstadt, Germany. I was the lead and corresponding author for this paper. The co-authors made valuable contributions in conceptualising and reviewing the paper.

agency and institutional change (Heiberg et al., 2022; Miörner et al., 2022; Fünfschilling, 2019; Fünfschilling and Truffer, 2016), we apply the concept of institutional work (Lawrence and Suddaby, 2006). A closer look on enabling conditions for institutional work accounts for associated motivations, expertise and assets and explains which actors and sector-specific endowments are associated with strong agency (Duygan et al., 2021b; 2019). Thus, we aim at explaining how institutional work activities condition the specific reconfiguration of system boundaries. Specifically, we suggest that the reconfiguration of system boundaries may take four main forms: missing couplings due to failing institutional work; an overlap of both systems in case actors from both fields succeed in creating couplings; changing market shares, when actors affiliated to one system find themselves better positioned to enhance their enabling conditions and diversify business activities; and finally, interface actors may create couplings and deliver required products and services.

The markets for residential storage systems and electric vehicles in Germany serve as case study. Combining private stationary storage systems with photovoltaics enables their users to increase the consumption of self-produced electricity. While initially actors affiliated to the electricity system, such as electric utilities or storage manufacturers, were the key players in this market, automobile companies are increasingly advancing into the market. Current business models encompass services in the field of mobility, such as private charging points or the leasing of vehicles. Hence, these offers are not solely delivered within the electricity system, but also by automobile manufacturers providing energy management systems, storage systems and green electricity along with electric vehicles. Correspondingly, automobile manufacturers also engage in institutional work in order to create smooth connections between the systems in technological, actor and institutional dimensions.

After presenting the conceptual background and methodological approach, this paper presents the institutional environment of the German electricity sector and depicts institutional work carried out by actors affiliated to the electricity and automobile system. We discuss which specific activities and preconditions stand out for strong agency and, thus, influence the way the different systems become connected.

5.2 Multi-system interactions and institutional work

5.2.1 Multi-system interactions in transition studies

Multi-system interactions capture how different relatively unconnected socio-technical systems and the associated actors, institutions and technologies become closely connected in the course of transitions. For example, decarbonization efforts require a better integration of the electricity sector with e.g. transport and heating (Löhr and Chlebna, 2023; Rosenbloom, 2019; Markard, 2018). Multi-system interactions have been conceptualized in different ways. Earlier contributions have focused on niche developments (Sutherland et al., 2015; Papachristos et al., 2013; Raven, 2007; Raven and Verbong, 2007; Geels, 2007) addressing, for instance, institutional and material ties of niches with multiple systems. Geels (2018) takes a more distributed view of change, including landscape forces as well as the interaction of multiple niche innovations within and across regimes. As regards relations between socio-technical regimes, Konrad et al. (2008) differentiate functional and structural couplings. Structural couplings relate to actors, infrastructures or institutions, which are used by two regimes (e.g., shared industry association representation) and are likely to result in synergies. Functional couplings refer to input-output relations between different complementary regimes often leading to co-evolutionary dynamics

(e.g., the diffusion of electric vehicle resulting in an increasing electricity demand). In a similar vein, research on complementarities focuses on positive interactions between sectors and technologies in technology value chains, such as newly adopted technologies triggering technological change in input sectors (Mäkitie et al., 2022; Markard and Hoffmann, 2016).

While many of these earlier studies examine the nature of couplings and interactions from a system perspective, more recent contributions (Kanger et al., 2021; Rosenbloom, 2020; Andersen et al., 2020) revisit this work and emphasize the complexity, fluid nature and multi-dimensionality of multi-system interactions. Rosenbloom (2020, 338) highlights the role of agency and political conflict, since *"actor networks […] diffuse knowledge, practices, and institutional logics across systems".* Similarly, Kanger et al. (2021, 53) call for more research on types of actors operating across systems and on *"their perceptions, actions, and conflicts […] power and capacity to mobilize transition arenas".* The most recent research focuses more on concrete activities of actors connecting multiple systems. For instance, Andersen and Geels (2023) propose causal processes how actors generate new couplings between systems concerning technologies, actors and institutions (e.g., business models diversifying into other systems or actors engaged in institutional work to create institutional alignments). Löhr and Chlebna (2023) examine the activities and characteristics of system entanglers engaged in hydrogen-based pilot projects using the concept of transition work (institutional work attuned to transitions). Studying the example of the electrification of passenger ferries in Norway, Andersen et al. (2023a, 9) scrutinize nexus-building processes across technological, agentic, institutional, and material resource dimensions. They suggest that *"insights from research on institutional work and dynamics of organizational fields"* are needed to further conceptualize interface-building processes. We take this as starting point for operationalizing agency by means of institutional work, which allows us to focus on the role of institutional work as conditioning factor for the reconfiguration of multiple systems in the course of transitions.

5.2.2 Institutional work and multi-system interactions

Multi-system interactions are usually structured in the three dimensions of technologies, actors, and institutions (Andersen and Geels, 2023; Löhr and Chlebna, 2023; Rosenbloom, 2019; 2020). Rosenbloom's sites of interaction concern the relationship of technological innovations and existing system elements, changing system boundaries with respect to institutions and the role of actor networks in redefining institutions and technology applications within and across systems (Löhr and Chlebna, 2023; Rosenbloom, 2020). Reconceptualizing structural and functional couplings by Konrad et al. (2008), Andersen and Geels (2023) consider structural couplings to exist rather between (than within) systems and to give rise to new (functional) resource flows. The cross-system interoperability of transport and electricity, for instance, requires new couplings like charging technology, regulations, and standards for its equipment, operation, and payments, which are potentially provided by multi-system interface actors (Fig. 7).

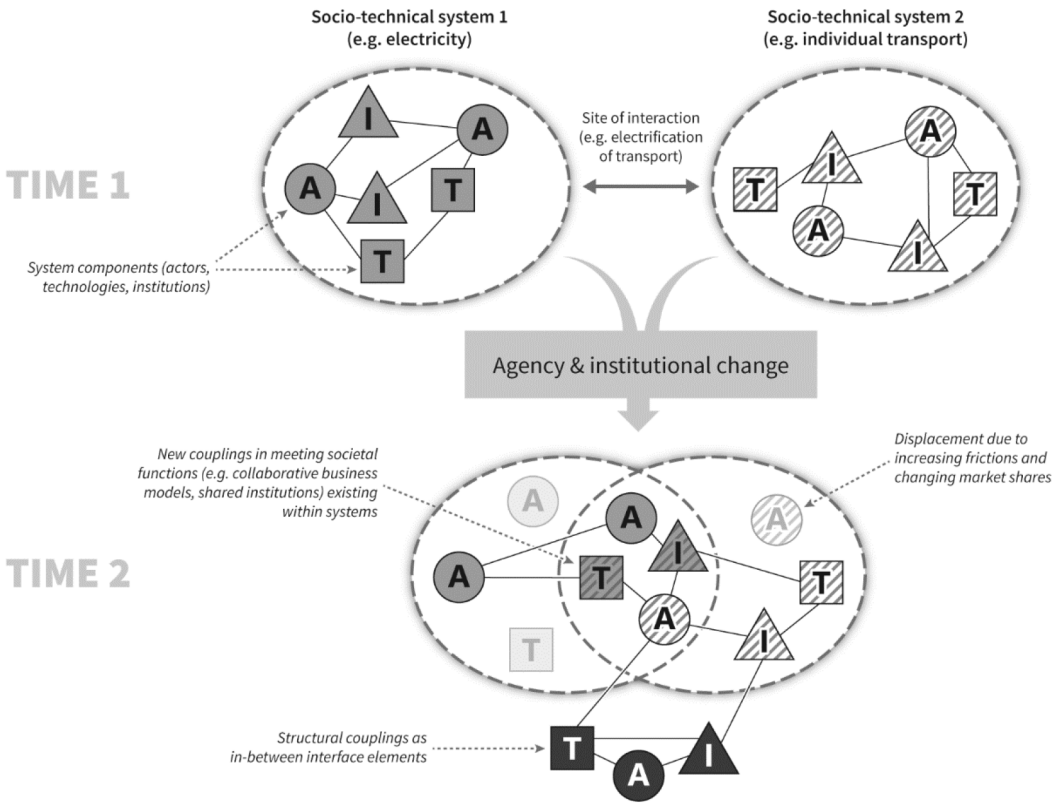


Figure 7: Agency and institutional change in sites of interactions and the resulting changes of system boundaries. Source: Own elaboration, adapted from Rosenbloom (2019).

We agree with Andersen and Geels (2023), who consider actors creating institutional couplings a causal process for multi-system interactions. Focusing on institutions (Geels, 2020; Fünfschilling, 2019; Markard et al., 2016a), regimes are characterized by a dominant set of idiosyncratic formal (e.g., policies, regulations, standards) and informal institutions (e.g., norms, routines, visions) that actors comply with and reproduce, which results in stability (DiMaggio, 1988; DiMaggio and Powell, 1983). In the course of transitions, these mature fields are challenged by emerging and competing institutional rationalities, which often evokes tensions (Fünfschilling and Binz, 2018; Fünfschilling and Truffer, 2014; Kemp et al., 1998). Regarding the intersection of multiple systems, this implies that the scope of (in)compatibility between system-specific institutions influences the creation of new couplings. Institutional mismatches, such as disagreements and uncertainties over rules, roles, and objectives, among actors affiliated to different systems, might potentially hamper cross-system actor collaboration. Actors can mitigate initial misalignment towards compatible cross-system institutional couplings, which enable functional resource flows (Andersen and Geels, 2023; Andersen et al., 2023a).

Responding to Andersen et al. (2023a), we operationalize these efforts to create institutional couplings with the concept of institutional work (Lawrence et al., 2009; Lawrence and Suddaby, 2006), which has increasingly been featured within transition studies (e.g., Löhr et al., 2022; Madsen et al., 2022; Kivimaa et al., 2021; Becker et al., 2021; Kainiemi et al., 2020; van Doren et al., 2020). This framework analyses concrete micro-level activities, which individual and collective actors pursue in order to induce divergent institutional change. Lawrence and Suddaby (2006) identified distinct activities, which aim at both the mobilization of rather tangible resources, such as political power, money, knowledge or social capital, and the (de-)con-

struction of rationales and thereby shaping discourses. While some activities have been associated with the creation of institutions (e.g., *advocacy*, *educating*), the maintenance of institutions covers the idea of a constant need of ensuring compliance with existing institutions (e.g., by *policing* or *deterring*). Work aiming at the disruption of institutions undermines the compliance of actors with institutions by making them less attractive and delegitimizing them (e.g., by *officially changing rewards and sanctions*) (see Appendix C for the full list of institutional work types by Lawrence and Suddaby, 2006).

In carrying out institutional work in multi-system settings, actors have to reconfigure their capabilities and gather knowledge about rules, processes, actor roles etc. in hitherto foreign systems (e.g., by collaborating with existing actors in that system) (Andersen and Geels, 2023; Andersen and Gulbrandsen, 2020; Steen and Weaver, 2017). In order to better understand how actors attain strong agency to be effective in institutional work, we propose to take account of the foundations of actors' agency from a sector-sensitive perspective and complement the institutional work framework with the key elements enabling institutional work according to Duygan et al. (2019).

5.2.3 Enabling conditions for institutional work and system affiliation

Understanding the resources and features that orient actors towards institutional work allows for addressing questions on what attributes are required for different forms of institutional work, and why some actors create a higher impact on institutional arrangements than others (Duygan et al., 2021a, b). Therefore, sectoral field conditions as well as the structural position of actors need to be taken into account (Battilana et al., 2009; Battilana and D'Aunno, 2009). We consider this a highly relevant refinement for our case, as actors affiliated with different industries might be more or less effective in respect to certain activities compared to others. Thus, we refer to Duygan et al. (2019) who, based on a literature review of institutional entrepreneurship and institutional work, have identified resources, discourses and networks as key constituent elements for institutional work.

Physical-material resources refer to material artefacts, such as infrastructures or technological elements, which potentially lead technology suppliers and operators to induce a lock-in in order to benefit from path-dependency. Financial resources consist of capital, funds and monetary stocks that are crucial for activities like lobbying or running large-scale media campaigns (Duygan et al., 2019; Binz et al., 2016). Intellectual resources encompass mental abilities, expertise and experience. Finally, politico-judicial resources mean the formal authority of actors facilitating their access to decision- or policy-making venues or political instruments such as veto (Duygan et al., 2019; Lawrence and Suddaby, 2006). Discourses are understood as coherent storylines articulating visions and expectations and creating the legitimacy of an innovation. Through narratives, actors frame how current problems look like and how these issues should be addressed (Smith and Kern, 2009). Finally, (social) networks reflect the collective character of agency, as actors might strive for building trust, gaining legitimacy and accessing complementary resources. Accordingly, resources, discourses and social networks are likely to be complementing one another when facilitating institutional work (see again Appendix C for the relationship of constituent elements and institutional work as suggested by Duygan et al. 2019).

5.2.4 Conceptual framework

Fig. 8 summarizes our conceptual framework. At a site of multi-system interactions (e.g., the electrification of individual transport), actors from both fields arguably aim at creating smooth connections between systems in technological, actor and institutional dimensions. Relying on the concept of institutional work (IW) (Lawrence and Suddaby, 2006), we focus on institutions and examine the type of actors and activities they carry out in order to create institutional couplings (e.g., by advocacy or defining). By relating to enabling conditions therefore (Duygan et al., 2019), we aim at explaining, which actors and (sector-specific) endowments are associated with strong agency to shape institutions. Referring to Duygan et al. (2021b, 3), strong agency is understood as *"the larger influence exhibited by some actors"* in changing institutional structures due to beneficial enabling conditions for institutional work. Taken together, we propose that a better understanding of institutional work along with sector-specific preconditions helps to explain the course of changing system boundaries.

We expect four different options for the reconfiguration of system boundaries: (a) Failing institutional work may lead to missing couplings. (b) Actors from both systems succeed in creating institutional couplings, which results in an overlap of both systems, potentially characterized by collaboration. (c) Actors affiliated to one system might be better positioned to enhance their enabling conditions for institutional work and create couplings corresponding to their interests. Thus, they would be more likely to diversify business activities and exploit emerging opportunities in the other system or in between the systems. (d) Moreover, there is the option of interface actors taking charge of creating institutional couplings and delivering corresponding products and services (e.g., technology, regulations, and standards for equipment, operation, and payments for charging).

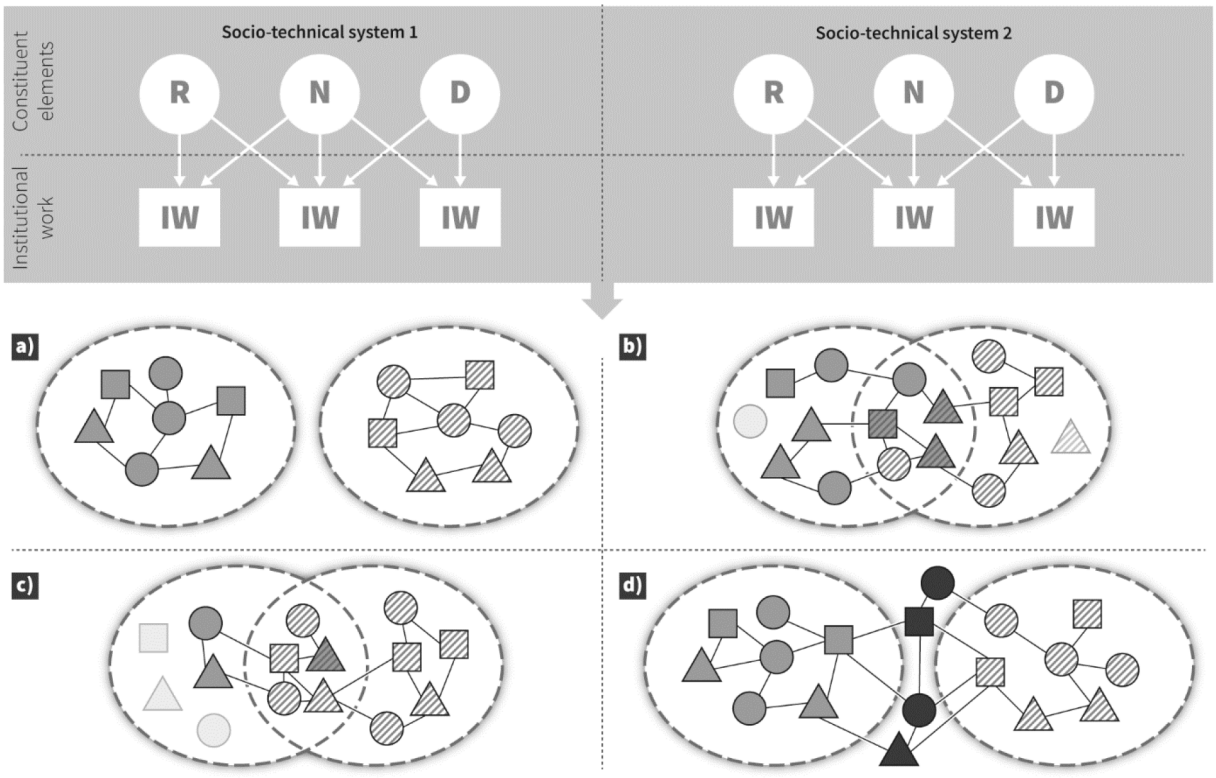


Figure 8: Stylised illustration of conceptual framework.
Source: Author's elaboration.

5.3 Case selection, methods, and data

5.3.1 Case selection: the electrification of individual transport in Germany

In order to gather deep insights about institutional work as a factor influencing the reconfiguration of multiple systems, we conduct a qualitative case study (Yin, 2018). We conceptualize the electrification of transport as empirical setting, which has been a widely used case in studies addressing multi-system interactions (e.g., Andersen et al., 2023a; Mäkitie et al., 2022; Rosenbloom, 2019). As a refinement, we focus on the end consumer markets of residential storage systems and electric vehicles, as interactions are observable in terms of technologies (1), actors (2), and institutions (3). As regards technologies (1), lithium-ion batteries can be used independently for residential storage systems and electric vehicles, but at the same time constitute the shared key technology for business models involving both applications. Furthermore, this interface requires (public and private) charging technology emerging between the systems. Concerning actors (2), we observe actors and organizations originally belonging to one system (e.g., automobile companies, electric utilities, ministries) as well as interface actors (e.g., providers of charging equipment). These actors fulfil different roles, in their original field or diversifying their activities into other fields (e.g., storage manufacturers providing car leasing). (3) Institutions spanning the boundaries of both systems are needed, for instance, standards (e.g., on operation, payment) as well as regulation (e.g., on grid connectivity) ensuring the interoperability of charging. Furthermore, political regulation embedded within one system addressing specific targets, such as the feed-in tariff of renewable energies, needs to be attuned to interactions coming from the transport sphere. Relating to end consumer markets, informal institutions manifest themselves as public discourses and consumer conventions, which may face rather traditional mind-sets on the side of grid system actors.

Regarding these dimensions, Germany constitutes an emblematic case (Flyvbjerg, 2006). In general, the markets for residential energy storage systems with a maximum capacity of 30 kWh as well as for electric and hybrid vehicles have been characterized by massive rises in sales. The market for residential storage systems is the biggest in Europe in absolute terms and relative to population (ees Europe 2023, see Fig. 9). From a technological perspective (1), we have seen advances in battery technology in terms of materials, life spans and capacities leading to new application possibilities (Figgener et al., 2021). Combined with photovoltaics, storage systems can be used in residential energy management systems in order to enhance self-production and -consumption of electricity, also known as prosuming. More precisely, storing surplus electricity beyond current consumption increases the share of self-generated electricity among total electricity consumption in a household (Tepe et al., 2021; Kairies et al., 2019).

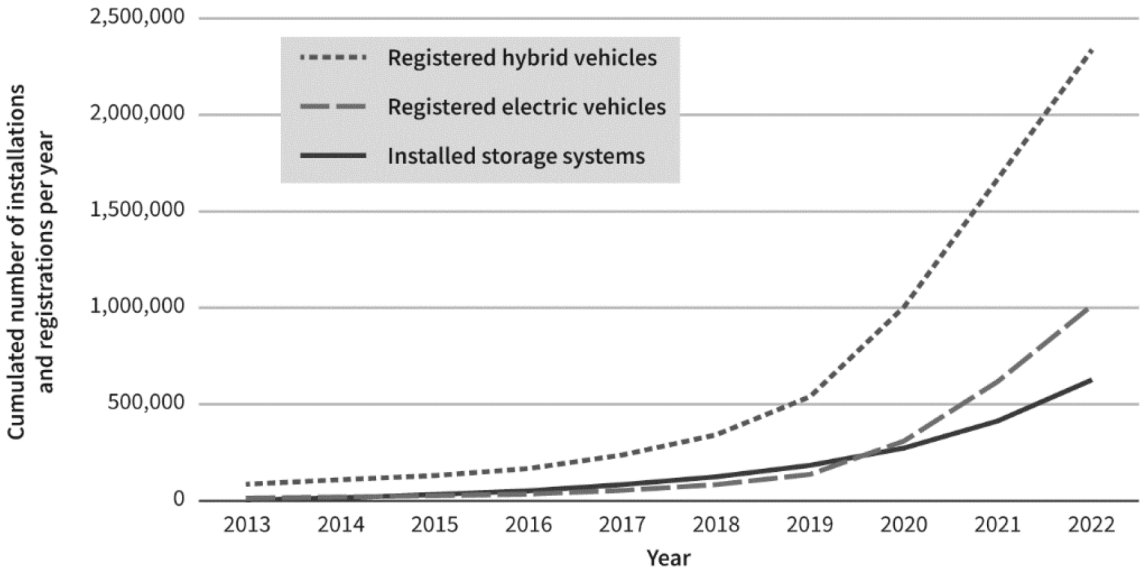


Figure 9: Cumulated installation figures of stationary residential energy storage systems (up to 30 kWh) and stock of licensed passenger cars with electric or hybrid engines for the years 2013 until 2021 in Germany, estimated and rounded values at year-end.
Source: Bundesverband Solarwirtschaft e.V. (2023), Kraftfahrt-Bundesamt (2023a).

Besides self-consumption, business models increasingly encompass so-called 'multi-use' applications (Blasch et al., 2021; Mlinarič et al., 2019). For instance, large numbers of digitally aggregated photovoltaic and battery systems can be used for frequency containment reserve in order to balance variation of mains voltage by the withdrawing or storing of electricity in cases of grid disruption or overproduction (Sousa et al., 2019). Most importantly, batteries of electric vehicles are integrated into energy management systems, also including photovoltaics and stationary storages. The main aim is to facilitate vehicle charging with self-produced electricity (Rücker et al., 2022; Costa et al., 2022). Some business models even include leasing agreements for electric vehicles (e.g., sonnenDrive). As a further step – so far not implemented due to missing regulation – frequency containment reserve could be provided by bidirectionally charging mobile electric vehicle storages, known as vehicle-to-grid.

As regards actors (2), the supplier side is increasingly spanning boundaries (Costa et al., 2022). Prior to the integration of mobility services, the business models were mainly provided by medium-sized storage manufacturers (e.g., sonnen or E3/DC) and rather small green electricity providers (e.g., Lichtblick or Polarstern), followed by big electric utilities (e.g., EnBW, E.On) (Zademach and Käsbohrer, 2022). Nowadays, full-package offers potentially encompassing photovoltaics, stationary storage systems, electric vehicles, wall boxes, energy management software and residual power contracts are often collaboratively provided by both sectors (e.g. Mercedes Benz in cooperation with E.On, BMW with Solarwatt, or Tesla with Octopus Energy Germany). The Volkswagen Group has independently started to provide a full-package offer including green residual electricity along with electric vehicles and even mere electricity contracts without an electric car (Volkswagen Naturstrom in Fuhs, 2021). Charging tariffs, which regulate the contractual accounting at public charging points, are also offered by both, electric utilities (e.g., EnBW mobility+, E.ON ÖkoStrom Home & Drive 24) and automotive companies (e.g., BMW charging, Audi charging, Mercedes Me Charge).

The different use cases of these business models require the alignment of the regulatory framework (3). In fact, we have seen amendments of key regulation in Germany during recent years.

According to Duygan et al. (2019; 2021b), observing decision- or policy-making instances influencing institutional arrangements, such as revision of laws, technology standardization processes, or funding schemes, can provide a reference for assessing agency since actors typically try to influence formal institutions to direct the course of transitions. In spite of these amendments, the regulatory framework is still considered the main barrier for a further development of abovementioned business models, which emphasizes our focus on institutional work as influencing factor for changing system boundaries. The revision processes will be elaborated on in Section 5.4.1.

5.3.2 Data collection and analysis

The empirical analysis draws on the triangulation of different qualitative methods and data sources. Our market knowledge is based on extensive desk based research including market data, reports by utilities, ministries and industry associations as well as company websites and legal texts. We further draw on participant observations during 42 working group meetings of a German industry association in the electricity system, which members participate in to get informed about market trends, innovative developments and regulatory changes as well as to organize their institutional work targeting regulation (for a list of subjects see Appendix D). The association's members are mostly affiliated with the electricity system (e.g., electric utilities, Distribution System Operators (DSOs), storage manufacturers), but increasingly also with the automotive industry (e.g., car manufacturers, suppliers in the field of charging). The meetings lasted between 60 and 180 min and took place between September 2020 and February 2023.

For the purpose of a data and perspective triangulation (Flick, 1995), we conducted a total of 32 semi-structured interviews with both electricity and automotive sector experts and industry leaders, ranging from academics, government officials and lawyers to representatives of utilities, industry associations, DSOs and Transmission System Operators (see Appendix E). The first interview partners were either members of the aforementioned industry association or identified through desk based research, whereas further experts were sampled based on recommendations from those interviewed (snowball method). The sampling strategy targeted senior experts from both industries directly involved in institutional work or having an explicit knowledge about the market. The interviews were conducted by phone or videoconferencing software between February 2021 and May 2023 and lasted about 75 min on average. All but five interviews were recorded and transcribed verbatim. Extensive notes were gathered in the unrecorded ones.

We first asked the interviewees to describe the main obstacles to the implementation of new business models. With energy regulation being considered as the main barrier in almost all interviews, we further asked the interviewees to identify actors and organizations influencing regulation, their concrete actions as well as their enabling or constraining preconditions in order to push their particular agenda. We also covered further institutional work activities targeting formal (e.g., standards) and informal institutions (e.g., public discourse). The agency of actors is indicated by the extent of influence their institutional work had on changing relevant institutions. We assessed their agency through actual decision- and policy-making interventions, the salience of their arguments and activities, their network positions and endowment with resources as well as cross-validated statements about the estimated impact (Duygan et al., 2021a). The empirical material was subject to a qualitative content analysis based on a coding scheme

that was informed by the theoretical assumptions (Mayring and Fenzl, 2019). During the coding process, the scheme itself was constantly refined (for exemplary quotes see Appendix F).

5.4 Analysis

5.4.1 Institutional context and regulatory changes

The aforementioned business models contradict the rationality of a rather centralized electricity supply, which is mainly promoted by the *Federal Network Agency*[9] (BNetzA), part of the *Ministry for Economic Affairs* (BWWK, especially until the end of 2021[10]), several (mostly municipal) electric utilities and DSOs[11] along with their industry associations. The regulatory framework (mainly *Erneuerbare- Energien-Gesetz, EEG*, and *Energiewirtschaftsgesetz, EnWG*) is regarded by industry experts as being the central obstacle to a more profitable realization of the business models, since, for instance, some multi-use applications are associated with double grid fees, taxes and surcharges as well as high measurement requirements. Regulation regarding vehicle-to-grid is missing at all (see Tables 5 and 6).

As regards amending EEG and EnWG, formal decision-making power lies with the German federal parliament. The substantive work on the legislation mainly resides with the BMWK. Although being intended as downstream, executive authority, the BNetzA provides extensive advisory services to the ministry, thereby voicing its critical attitude towards residential storage systems. However, there have been changes benefitting a more profitable implementation of the business models. Among others, in 2023, the EEG surcharge was suspended (see again Tables 5 and 6; for a more detailed overview of the policy processes and actors involved see Appendix G). The next chapters shed light on the enabling conditions for and concrete activities of institutional work inducing these and further changes.

[9] The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur, BNetzA) is a separate higher federal authority aimed at guaranteeing the liberalization and deregulation of the markets for telecommunications, post and energy via non-discriminatory network access and efficient system charges (BNetzA, 2023a).

[10] After taking office at the end of 2021, the new leadership of the then called Ministry for Economic Affairs and Climate Action (BMWK) (Bündnis 90/Die Grünen, Alliance 90/The Greens) has been influencing some regulatory changes of the EEG 2023 and the EnWG 2022 benefitting a more decentralized electricity supply.

[11] Regarding the approximately 870 German DSOs, our empirical material indicates great heterogeneity with some stakeholders welcoming residential storage systems and even launching research projects, but the large majority being critical towards them.

Table 5: Main regulatory barriers in EEG and the respective changes through recent amendments relevant for business models involving residential storages and electric passenger cars (still existing barriers in italics).

Main regulatory barriers in EEG 2017	**Main regulatory barriers and changes in EEG 2021**	**Main regulatory barriers and changes in EEG 2023**
Installation of photovoltaics and storage systems highly complex bureaucratically.	Easier grid access for storage systems (§8 Abs. 5 S. 3 EEG).	
Missing definition of 'energy storage', instead treatment as consumer and generation facility (§ 3 Nr. 1 EEG).		In 2023, new definition of energy storage as new category besides generation, transport and consumption in EnWG (§3 Abs.15d), not yet in EEG. *However, one-year time limit to incorporate definition in main regulatory frameworks.*
Threshold for total exemptions of grid fees, taxes and (EEG-) surcharges at 10 kWh (§ 61a Nr. 4 EEG), de-facto double charging with grid fees, taxes and (EEG-) surcharges for installations > 10 kWh in the course of storing and withdrawing electricity from the storage (grid services) due to high and complex measurement requirements (§§ 60, 61l EEG). Regarding EEG-surcharge, in any case 40% each time for storing and withdrawal of electricity (§ 61b EEG).	Threshold for exemptions of grid fees, taxes and surcharges set from 10 kWh to 30 kWh for new and existing installations (§ 61 Abs. 1 EEG). § 61l EEG simplified, grid services involving storing and withdrawing electricity from the storage possible for prosumers without double charging with taxes and (EEG-) surcharges. *However, not applied to grid fees and still highly complex in terms of measurement requirements.*	Suspension of EEG surcharge (§ 58 EEG). Simplified measurement at grid connection point (behind-the-meter): most fees and taxes only relate to withdrawals from and feed-ins of electricity to the grid, balancing of electricity flows (acc. to §21 EnFG 'Energiefinanzierungsgesetz', former § 61l EEG). *However, still contested: grid fees and electricity taxes in multi-use applications.* Storage losses are exempt from charges and fees (§ 21 EnFG).
Energy communities not implemented. Furthermore, joint production and usage of renewables by self-consumers located in the same building hampered by regulatory and bureaucratic requirements (§ 3 Nr. 19 EEG; §§ 21b Abs. 3, 23b EEG).	Joint production and usage of renewables by self-consumers located in the same building (landlord-to-tenant electricity) facilitated, as electricity can be delivered by a third party instead of the facility operator itself (§ 21 Abs. 3 EEG). Furthermore, higher government subsidies for projects in rental apartments (§ 48 EEG).	
Separation of green and conventional grid power as well as self-consumed and fed-in electricity flows, leading to complex metering of different electricity flows and hampering multi-use of storage systems (§ 3, Nr. 1 EEG; § 61l EEG)		

Main regulatory barriers in EEG 2017	Main regulatory barriers and changes in EEG 2021	Main regulatory barriers and changes in EEG 2023
	Introduction of regulation for pv systems older than 20 years (§ 3 Nr. 3a EEG; § 19 EEG).	New rates of feed-in compensations for prosumers completely and partly feeding in (involving self-consumption) with the latter being reasonably high and, thus, enhancing the installation of a storage system in addition to photovoltaics (§ 100 Abs. 4 EEG).

Source: Erneuerbare-Energien-Gesetz (EEG) Bundesministerium der Justiz (2023b).

Table 6: Main regulatory barriers in EnWG and the respective changes through recent amendments relevant for business models involving residential storages and electric passenger cars (still existing barriers in italics).

Main regulatory barriers in EnWG 2011	Main regulatory barriers and changes in EnWG 2021	Main regulatory barriers and changes in EnWG 2022
Missing definition of 'energy storage' as well as mobile storages, instead treatment as consumer and generation facility (§ 3, Nr. 15 EnWG).		In 2023, new definition of energy storage as new category besides generation, transport and consumption (§3 Abs.15d EnWG). *However, one-year time limit to incorporate definition in main regulatory frameworks.*
Double charges with grid fees and charges (§ 19 Abs. 2 EnWG, § 17f Abs. 5 EnWG 'offshore grid fee' § 48 EnWG 'concession fee'), double charges with grid fees (§ 118 Abs. 6 EnWG).	Fees and charges measured analogously to § 61l EEG. *However, not applied to grid fees (§ 118 Abs. 6 EnWG).*	
No regulation for bidirectional charging, e.g. grid charging periods of private electric vehicles (§ 14a EnWG)		*(Forthcoming, BNetzA in charge of regulation for grid charging periods allowing DSOs to control storage systems in exceptional cases (§ 14a EnWG))*

Source: Energiewirtschaftsgesetz (EnWG) in Bundesministerium der Justiz (2023a).

5.4.2 Institutional work and enabling conditions

5.4.2.1 Electricity system

5.4.2.1.1 Actors with strong agency

Actors advocating the usage of residential storage systems potentially accompanied by e-mobility services are mainly the providers of these business models, that is storage manufacturers, rather niche green electricity utilities, but also the big conventional utilities (see Section 5.3.1). With respect to institutional work, interviewees identified big electric utilities and particularly industry associations as having decisive impact on policy processes, to a lesser extent storage manufacturers. Industry associations are the main stage for mobilizing allies and collective institutional work. There is a broad landscape of associations; part of our empirics were industry associations representing the solar industry, the production of renewables or the storage industry. By contrast, the influence of NGOs seems to be rather weak.

5.4.2.1.2. Enabling conditions

Discourses. The central narrative around the mentioned business models is concerned with the advantages of a decentralized, prosumer-driven electricity supply. Storing electricity allows for a flexible adjustment of load and generation, which is indispensable due to the further integration of renewable energies. The combination of storage systems and e-mobility increases the self-consumption of electricity. Especially industry associations highlight profitable use cases, such as frequency containment reserve (see chapter 5.3.1), which require regulatory adjustments (regarding fees, charges, and metering, see chapter 5.4.1). Particularly regarding advocacy, customers' benefits and fostering the overarching political targets of expanding renewable energies are considered salient arguments.

Another argument for advocacy work is the lacking compliance with EU legislation. Especially industry associations point to the necessity of aligning German regulation with EU legislation, which claims beneficial regulatory changes such as higher thresholds for exemptions from fees and surcharges (see chapter 5.4.1). The effectiveness of this argument is contested, as BMWK and BNetzA representatives argue that EU legislation is implemented pointing to inaccuracies in EU legislation, instead. Similarly, some interviewees (industry associations, electric utilities) consider rather the high complexity of regulation (e.g., metering requirements) as main reason for unfeasible business models. When it comes to advocating regulative changes towards politicians (esp. parliamentarians), the investigated industry association highlights the argument of supporting SMEs. A further development of business models would benefit SMEs dealing with developing, manufacturing and installing energy management systems including storages. Regarding public discourse and promotional activities, electric utilities and storage manufacturers highlight rather emotional aspects, such as autarky, contributing to the expansion of renewable energies and technology enthusiasm. Further arguments are financial savings and backup power supply.

> *"So storytelling in its purest form. Whether it always pays off, whether it all makes sense, that's often irrelevant. The customer wants to feel good. He wants to understand something." (Interview 8)*

Social networks. The high relevance and legitimacy of industry associations reflect the collective character of agency and the importance of networks for institutional work. Networks facilitate advocacy particularly by increasing credibility, especially if competitors or incumbent actors, such as DSOs, are involved:

> *"By addressing position with others, you increase your credibility […]. If you also have a DSO on board, that's even better. Then […] you have fixed this problem." (Interview 11)*

In this multi-system setting, an important feature of networking is bridging different actors groups that are otherwise not collaborating. This is illustrated by automobile companies becoming members of industry associations in the field of electricity. Vice versa, representatives of industry associations state that they benefit from the lobby weight of automobile manufacturers:

> *"The car lobby is incredibly strong in Germany. […] Well, they just use the political contacts they have in the [industry association in the electricity system] to mobilize the forces that then work in the same direction." (Interview 12)*

Moreover, cross-sectoral networks are necessary for defining, when it comes to initiate joint research and pilot projects, which aim at advancing technical standards (e.g., for measurement technology, reusing of mobile batteries for containment frequency reserve).

Resources. Electric utilities and storage manufacturers themselves lack formal authority over decision or policy-making. Their access is mainly limited to institutional work activities. In financial terms, many small, often municipal and unbundled utilities, handling the generation and distribution of electricity, lack capacity to be a member of industry associations. The same applies to SME storage manufacturers. Thus, big electric utilities are more likely to engage in advocacy work. Furthermore, large companies are able to invest in R&D, to start pilot projects, to cross-subsidize them, or to take the risk of making advance payments for the charging infrastructure, which is important for theorizing and defining. As regards intellectual resources, especially big electric utilities possess high knowledge on the regulatory environment in the electricity sphere due to longstanding memberships in industry associations or in-house lawyers. However, electricity system actors (such as electric utilities) are mostly lacking experience in terms of digital tractability (e.g., communication interfaces), which hampers, for instance, defining activities for intelligent charging.

Physical-material resources mainly concern the physical components of business model devices as well as the charging infrastructure. Public charging points are mainly operated by electricity system actors, such as electric utilities, metering point operators and DSOs,[12] but also by petroleum and automotive companies as well as by public authorities, major employers and commercial enterprises (e.g., supermarkets).[13] The argument of taking on social responsibility and serving the overarching energy transition by operating public charging infrastructure gives legitimacy and credibility:

> *"If you come across as a doer, then you have more weight than writing position papers without being active in this business model yourself." (Interview 25)*

[12] According to the EU rule of unbundling electricity production and supply interests from the network of 2021 (in German regulation §7c Abs. 2 EnWG 2021), DSOs are only allowed to operate charging points in peripheral regions after market failure.

[13] In Germany, the operators with the most charging points are EnBW mobility+ AG und Co.KG, E.ON Drive Gmbh, Tesla Germany Gmbh, EWE Go Gmbh and Lidl (BNetzA, 2023b).

When it comes to business model devices, transferring expertise and eventually specific products and services from the automobile to the electricity system comes with challenges. While it is feasible for electricity system actors to integrate storage systems into their business models (also by means of shareholdings) and e-mobility services such as charging tariffs, the integration of hardware is practically constrained to charging or leasing cooperations with automobile manufacturers. This again hampers, for instance, defining standards for bidirectional charging or grid connectivity for electric vehicles.

5.4.2.1.3. Institutional work.

Regulative institutions (see again chapter 5.4.1) are the most important target for actors seeking to promote residential storage systems, especially for industry associations. One key task is to *educate* their member firms about recent regulatory changes and to discuss the associated consequences for their business models. The other main activity is *political advocacy* towards policymakers, such as ministries, network agencies or political parties (esp. parliamentarians) by means of, for example, opinion papers or associations' hearings. These papers inform about companies' regulatory requirements and aim at creating an appropriate institutional environment to further promote the aforementioned business models (e.g., by claiming reliefs from charges and fees). In order to influence the cognitive frames of policy makers, they *theorize* the benefits of a decentral electricity supply.

Press releases and position papers are also published by single stakeholders, like electric utilities, or *in normative networks* with other actors including competitors across sectors. The same applies to hosting and participating in conferences on cross-sectoral topics such as bidirectional charging. However, such cross-sectoral collaborations aiming at *political advocacy* happen rather ad hoc and on specific topics (e.g., proposing amendments on specific laws).

Particularly electric utilities are part of cross-sectoral research and pilot projects often involving automotive companies and DSOs. The aim is to *define* technical and regulatory standards, in order to ensure cross-system inter-operability (e.g., communication interfaces for grids, smart meters and vehicles or developing charging algorithms for car parks).

In addition to regulative institutions, cognitive and normative institutions can be relevant for enhancing the legitimacy of a product (Duygan et al., 2021a). In advertizing the aforementioned business models through public outreach campaigns (also via social media), providers often *construct an identity* of individuals actively contributing to the energy transition or being part of an autarkic energy community.

5.4.2.2. Automobile system

5.4.2.2.1. Actors with strong agency

Big manufacturers and industry associations (especially VDA, *Verband der deutschen Automobilindustrie*) are regarded as having the strongest agency to induce institutional changes, which promote the further diffusion of business models at the interface of residential storage systems and e-mobility. Especially German automobile manufacturers are engaged in institutional work. In addition, particularly shaping public discourse and building up charging infrastructure, *Tesla* is deemed a further prominent player. Besides VDA, other, rather in-between associations, for instance, specialized in e-mobility, carry out institutional work.

5.4.2.2.2 Enabling conditions.

Discourses. In general, automobile companies and industry associations share the narrative of a decentral, prosumer-driven electricity supply. Furthermore, bidirectional charging is depicted as solution for issues of grid stability through intelligent charging, at best accompanied by flexible electricity tariffs.

> *"But they [automotive industry] are actually very clever, by addressing problems that arise, especially regarding grid expansion, grid stability and bottlenecks, saying that they contribute constructively to the solution. […] Of course, this also indicates a certain level of competence in the eyes of decision-makers." (Interview 25)*

Social networks. Most strikingly, we observe cross-sectoral networking in industry associations. Associations of both fields are collaborating and automobile companies increasingly become members in industry associations in the field of electricity. Thus, automobile companies particularly aim at gaining knowledge about regulation and policy processes as well as access to political institutions to improve their preconditions for advocacy. Particularly rather incumbents' associations in the electricity sphere provide access to decision-making. Although the automotive industry has maintained close ties with the BMWK ever since, it is stated to lack access to the ministry's energy department and to BNetzA.

> *"Getting into the issues, getting into the circles, which they [automobile manufacturers] also try to do with our help [industry association in the electricity system]."(Interview 27)*

Moreover, automotive companies are increasingly requesting consulting services on energy regulation from specialized consultancies and law firms, which are typically advising DSOs, utilities or project planners. As already mentioned, cross-sectoral research and pilot projects are an important endowment crucial for defining standards directed towards interoperability (e.g., regarding charging).

Resources. Corresponding to the electricity system, access to political decision-making of automobile manufacturers and associations is limited to institutional work activities. Regarding finances, our insights suggest that automobile companies resemble big electric utilities in that there are financial resources for advocacy work (memberships in industry associations, business units for advocacy), defining, theorizing and vesting (research and pilot projects, R&D).

Concerning intellectual resources, the automotive industry is stated to build up electricity related expertise, for instance, by networking and recruiting.

> *"We [electric utility] also see that many employees who used to be in the energy industry in charge of regulatory issues and industry association issues went to [an automotive charging subsidiary], for example. So you can see that competences are transferred there as well. […] And we are pretty sure that there are the best contacts." (Interview 25)*

Regarding the transferability of energy related knowledge, some experts highlight the high regulatory standardization of electricity tariffs and argue that electricity supply itself does not require high levels of expertise and experience. In contrast, other industry experts emphasize electricity supply being a mass consumer business with complex and necessarily efficient administration and billing. Thus, only big automobile companies are expected to acquire the knowledge to profitably implement such processes. In terms of digitalization, technological

know-how is clearly associated with the automotive industry, which facilitates defining standards.

> *„The energy industry stands in its own way, whereas the automotive industry has the finger on the pulse. For example, there are far more standards in cars than in the grid […] that are sufficient to control cars." (Interview 31)*

As regards charging, automobile companies mainly operate fast charging points, such as the *Tesla Supercharger* or the *Ionity* high-performance charging station network along motorways.[14] While the charge point operator is responsible for the provision and the technical operation, the e-mobility provider contractually handles the tariffs, with the latter being increasingly assumed by automobile companies (e.g., *BMW charging, Mercedes Me Charge*).

Concerning the material components of business models, our interview partners almost unanimously regard the automotive industry in a better position since the vehicle itself makes up the largest proportion of value added of complete business models. Hence, the automobile companies are expected to more easily build up further competences and integrate electricity services, such as charging tariffs, or software and data applications, which are important preconditions for defining. Moreover, customers are likely to align their energy management system with this most expensive component, which is reinforced by the personal sales channel when purchasing a vehicle. In this context, some interviewees expect vehicle batteries to replace stationary storage systems due to vehicle-to-home, i.e. vehicle batteries able to provide electricity to households:

> *„Their [residential storages] role will probably change significantly with the further advent of e-mobility, because many of the [stock] storage systems are simply not suitable for charging electric vehicles. And the storage capacity of electric vehicles is larger, so that there may simply be a switch towards vehicles." (Interview 32)*

5.4.2.2.3. Institutional work

Automotive actors are increasingly carrying out *advocacy* work in the electricity sphere. §14a EnWG on controllable low-voltage consumption devices constitutes a striking example of the automotive industry intervening decision making in the electricity sector. In 2021, after an intervention of an automotive industry association, the former minister for Economic Affairs cancelled a draft law (§ 14a EnWG), which would have authorized DSOs to control charging periods of private electric vehicles.

> *"We [industry association in the electricity system] also had a very close alliance with the [automotive industry association]. Due to its tradition and its size, [the association] found its own access to the minister and the minister said: 'Ok, we'll stop that [§14a EnWG] because it's not going in the right direction.'" (Interview 1)*

As shown by this citation, there is collaboration in terms of *political advocacy* with stakeholders in the electricity system. §14a would also have affected residential storage systems and prevented customers from flexibly connecting their storages to the grid, making them less attractive.

[14] Ionity is a joint venture of the BMW Group, Mercedes-Benz Group, Ford Motor Company, Volkswagen Group with Audi and Porsche, and Hyundai Motor group based in Munich (Ionity, 2023).

Similarly to the electricity system, automobile companies publish joint position papers or host and participate in conferences on cross-sectoral topics in *normative networks*, also beyond industry associations. Cross-sectoral research and pilot projects involving automotive companies, DSOs, and electric utilities aim at developing technical and regulatory standards (*defining*). Furthermore, automotive companies and industry associations are mobilizing their storyline of bidirectionality being a solution to grid instability towards the media and political institutions in both sectors. Compared to residential storage systems, media coverage of e-mobility is assessed to be much higher. These discursive activities help to *change the normative associations* with e-mobility, which developed from being considered a rather niche topic for technology enthusiasts to having the image of a highly legitimized mainstream solution.

Upcoming tensions become evident as well. Interviewees in the electricity system (e.g., electric utilities) state that they feel increasingly put under pressure by automobile companies enhancing their intellectual resources and propagating the benefits of bidirectional charging. Furthermore, there is defining and *vesting* emanating from both fields about the communication interface for charging electric vehicles.

> *"Especially regarding the charging infrastructure or charging contracts, there are many efforts by the automotive industry, especially regarding this standard ISO 15118, which is about locating charging tariffs in cars and which […] decides who actually gets access to the customer in future. […] And these are topics where there is of course also friction between the energy and automotive sector, because, of course, everyone increasingly claims a part of the value chain for himself." (Interview 25)*

The automotive industry has been advocating for the so-called ISO 15118-communication standard enabling an electric vehicle to automatically be identified and authorized to a compatible charging station. Then, the charging tariff is pre-set in the vehicle. Alternatively, the charging contracts are being processed at the charging point via QR identification. Currently, both methods are possible.

To sum up, our results show a system reconfiguration, which resembles most option b (chapter 5.2.4, Fig. 10) in that actors from both systems are well endowed with features enabling institutional work and succeed in creating institutional couplings. This results in coupled formal institutions, such as regulation allowing for emerging business models or standards for the interoperability of charging, but also informal institutions like the growing societal and political legitimation of e-mobility and prosuming.

However, we observe tentative tendencies towards option c. Developing an inventory of business model innovation at the interface of mobility and electricity on a global level, this is confirmed by Costa et al. (2022, 9) stating that the *"confluence to date has been more about the automotive industry entering the electricity industry"* in terms of capturing additional services and revenue. In the next section, we discuss how institutional work activities along with actors' preconditions influence this reconfiguration and reflect on references to recent research on multi-system interactions and institutional work.

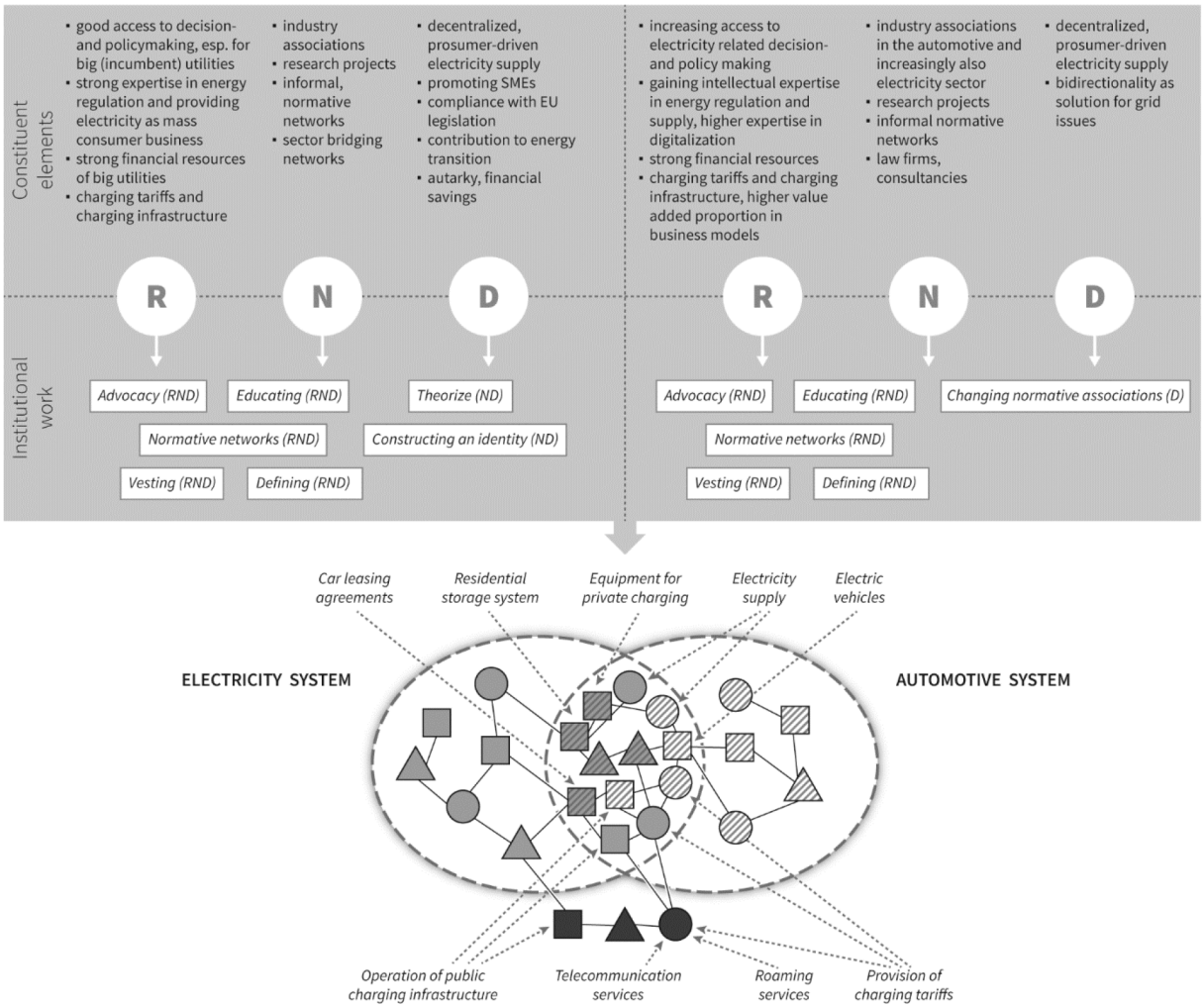


Figure 10: Key constituent elements of agency (resources, discourses and social networks) and related institutional work carried out by actors from the electricity and the automotive system.
Source: Author's elaboration.

5.5 Discussion

5.5.1 Actors with strong agency

Our empirical material suggests that in both fields the most effective agents in inducing institutional couplings are industry associations and big companies such as automobile manufacturers, electric utilities and to lesser extent storage manufacturers. However, in order to affect regulative institutions, single stakeholders mostly work together in associations. The same applies to some further in-between actors, such as the supplying industry for private charging equipment and manufacturers of power inverters or photovoltaics. Furthermore, we see collaborating associations across sectors or cross-sectoral networking within associations given that especially automobile manufacturers become members in associations in the electricity sphere. This corresponds to Löhr and Chlebna (2023), who identify cooperation between associations affiliated to different systems an important mechanism for system entanglement.

As regards the position of agents, Löhr and Chlebna (2023) highlight the need for new associations around emerging technologies or joint bodies of existing associations, arguing that system entanglers are more likely to be found in between or within both existing systems rather

than solely within their original system of competence. By contrast, we highlight the strong agency of traditional industry associations and incumbent, infrastructure-rich players (electric utilities, automobile manufacturers incl. subsidiaries for charging), who come with their sector-specific experiences and aim at gaining knowledge in the adjacent system. This shows that incumbents are capable of leveraging their resources to integrate disruptive technologies when they face political and societal pressure as well as economic incentives (Hellsmark and Hansen, 2020; Turnheim and Sovacool, 2020; Steen and Weaver, 2017; Bergek et al., 2013). In addition, we also found rather new actors, such as storage manufacturers (which we attributed to the electricity system), and industry associations covering cross-sectoral topics (e-mobility, electrical industry) to be active in institutional work.

Some interviewees expect the emergence of further business opportunities and in-between players filling the vacuum of unsolved conflicts between powerful incumbents, such as in the field of digital services and applications for charging (Andersen et al., 2023a), e.g. the recent emergence of roaming operators handling data traffic of public charging. Similarly, petroleum companies are expected to focus more on public charging infrastructure (e.g., in 2021, *bp* and *Volkswagen* announced to build up a fast-charging network, Aral, 2023). Some interviewees utter surprise at the fact that petroleum companies have not entered to the business of operating charging infrastructure earlier and to a greater scale. This ties in with Andersen and Geels (2023, 10) who expect *"probably third-party, in-between actors (or intermediaries)"* to monitor and manage the institutional and technological couplings, once these are created and sufficiently stable for the development of a market and new actor roles.

5.5.2 Institutional work and enabling conditions for creating couplings

A closer look on their enabling conditions explains the strong agency of (within system) industry associations and powerful incumbent players in fostering institutional couplings between systems. Corresponding to Andersen and Geels (2023) who highlight the relevance of cross-sectoral shared investments or joined ventures for accessing complementary assets such as knowledge or physical resource ownership, our focus on institutional work confirms that cross-sectoral collaboration (in industry associations) goes along with improving access to complementary resources. Especially automobile companies and associations seek access to political institutions and knowledge on regulation through electricity related industry associations, which enables them to engage in advocacy work on regulative institutions.

To some extent, the institutional work results in couplings benefitting both in a more system connecting way (Löhr and Chlebna, 2023), since the lobby weight of automobile manufacturers is particularly helpful in an institutional context characterized by reluctant grid actors (chapter 5.4.1). Examples for collaboration concern, for instance, private charging and accounting of company cars or successfully deterring the aforementioned controllability of charging processes on the part of DSOs in 2021 (§ 14a EnWG). In terms of discourses, both sectors share a common storyline of a prosumer-driven decentral electricity supply, with the market for home storages benefitting from the high media presence of e-mobility bringing battery technology to the fore.

5.5.3 Institutional work and enabling conditions resulting in increasing frictions

We also observe competitive and conflictive notions (Andersen et al., 2023a; Kanger et al., 2021; Rosenbloom, 2020; 2019) pointing towards option c, in the sense of changing market roles and shares. There is enormous competition about charging tariffs with automobile companies pushing into this market. Furthermore, there are automotive players providing full-package offers including electricity contracts along with electric cars or even mere electricity contracts.

Our insights reinforce the particular relevance of physical-material and intellectual resources. As regards the latter, especially automotive manufactures (incl. subsidiaries and industry associations) are well positioned to enhance their knowledge on electricity supply and regulation (relevant for *advocacy*, *educating*, *theorizing*), e.g., by cross-sectoral networking. Regarding extending business models, the transferability of knowledge is a crucial dimension. While supplying electricity is stated to be transferable due to its high standardization, electric utilities or storage manufacturers aiming at integrating e-mobility services are practically limited to collaborating with automotive stakeholders. Furthermore, electric utilities are regarded as not being versed in digital communication and tractability, which is an indispensable requirement for defining standards. Whereas Löhr and Chlebna (2023) speak of "*defining shared standards*" in a system-entangling environment, we find defining as means to advance into the other system in the material dimension of public charging. In the sense of vesting, automotive players gain a competitive advantage by putting standards on communication interfaces, which automatically connects vehicle and charging station. Furthermore, customers are likely to align electricity supply with their car purchase, being the most expensive component of business models. Some interviewees even expect vehicle batteries to replace stationary batteries due to higher capacities for vehicle-to-home and vehicle-to-grid applications (Costa et al., 2022; Kester et al., 2018).

Taken together, this case study links to Rosenbloom (2020) who claims research going beyond single patterns of symbiosis and competition and reflecting on the complex and changeable nature of these relationships.

5.5.4 Sectoral context

The specific sectoral context reinforces the importance of targeting regulative institutions by means of classic political advocacy, as the diffusion and feasibility of business models is strongly linked to national energy regulation (Duygan et al., 2021a). Consequently, this enhances the agency of traditional industry associations and powerful incumbents due to longstanding access to political institutions. Furthermore, strong agency is needed given within-system contestation (Madsen et al., 2022) due to reluctant grid actors influencing legislation. This corresponds to Andersen and Geels (2023) who expect bottlenecks rather about grid institutions (limiting expenditures on grid upgrades) and about actor orientations (cost optimization instead of innovativeness by grid actors) instead of technological challenges. In other circumstances, other actors, such as newly emerging interface actors, might have stronger agency.

5.5.5 Relation with institutional work

Regarding actors associated with strong agency for inducing institutional changes, our findings emphasizing incumbent, well-endowed players correspond to Duygan et al. (2019; 2021b), who find agency to influence Swiss waste management during policy revisions lying in the hands of

only a small number of actors necessarily endowed with large material and non-material resources. Being active and well embedded in networks is found as further sufficient complementary condition. Our results show, that this holds true for multi-system interactions. The specific multi-system setting is reflected by the importance of industry associations bridging different sectors for creating institutional couplings (Löhr and Chlebna, 2023; Löhr et al., 2022). In this vein, contradicting to Duygan et al. (2019), we would like to point out that networks have proven to leverage theorizing and educating.

Duygan et al. (2021b; 2019) emphasize the relevance of resources as being necessary, yet not sufficient conditions. Either (1) a high embeddedness in networks combined with a discourse utilizing various concepts or (2) a strong activity and embeddedness in social networks have to complement resources for strong agency in the specific case of influencing regulations in Swiss waste management. Regarding the last path, discourses seem to be important, yet not essential. While acknowledging the importance of resources and networks, our qualitative insights show that discourses are an indispensable element of all identified institutional work activities (Madsen et al., 2022). More concretely, our results confirm that a variety of arguments (benefitting the policy goal regarding renewables, customers' benefits, compliance with EU legislation, economic benefits for SMEs, individual's contribution to the energy transition) seems to be more salient than having moderate policy beliefs linking different discourse coalitions (Duygan et al., 2021b). The relevance of discourses for creating legitimacy in our case study might be reinforced by the specific institutional context (Duygan et al., 2019), since the consultation processes around amendments of the EEG and EnWG are rather transparent (including public associations' hearings) and renewables and e-mobility are associated with a strong normative dimension and high media coverage in Germany (Finstad and Andersen, 2023; Duygan et al., 2021a).

5.6 Conclusion

This case study contributes to the debate on multi-system interactions by explaining the reconfiguration of two systems with the help of institutional work. In order to take better account of sector-specific preconditions, we complement institutional work activities with enabling conditions. The markets of electric vehicles and residential storage systems in Germany serve as empirical case.

We find that incumbent, infrastructure-rich companies in both systems (big electric utilities, automobile companies along with business associations) are well placed to carry out institutional work and create institutional couplings. To some extent, we observe cross-sectoral collaboration, particularly concerning advocacy. However, increasing competitive notions become evident. Especially automotive companies are able to get access to policymakers and to complementary knowledge (e.g., on regulation) by means of cross-sectoral networks. Furthermore, they take advantage of their intellectual and physical-material resources (especially in terms of digital communication interfaces) for capturing emerging business opportunities and advancing into the electricity market, especially in the field of public charging via defining and vesting.

A first limitation of this study lies in the change of the German Federal Government at the end of 2021. Since then, the BMWK has been led by the party *Bündnis 90/Die Grünen* (*Alliance 90/The Greens*), which has been considerably influencing the regulatory changes of the EEG 2023 and the EnWG 2022. Thus, this could be an alternative explanation for institutional change

rivaling institutional work. However, there have been previous regulative changes. Furthermore, many civil servants in ministries and grid agencies kept their positions. Second, the categorization of electricity and automotive sector actors goes along with a certain homogenization. We assigned actors directly concerned with storages (e.g., manufacturers, industry association for storage technologies) to the electricity sector, as these actors were the pioneers in providing residential storage systems along with electricity contracts. Future research could stress intra-system differences as well as the time ordering of actor types carrying out institutional work.

Further potential for explaining institutional work in multi-system settings lies in system-specific differences in linkages to and power over upstream sectors providing, for instance, wall boxes, smart meters or battery modules. Furthermore, this field has recently seen a wave of acquisitions and shareholdings with players of the electricity, mobility and petrol sectors acquiring storage manufacturers, charging stations producers and telecommunications companies. The associated impact on capacities for institutional work merits further attention.

A recommendation for policymaking in this formative phase of two systems being interconnected would be to pay attention to inbetween, maybe less resourceful and connected actors, such as researchers or industry associations covering cross-sectoral topics. Interests of incumbent actors having strong agency might not necessarily direct towards the best possible solution for society. Nonetheless, in this fast changing, multi-dimensional field, policy frameworks need to respond quickly to requirements across sectors so as not to be a barrier constraining transitions.

6 **Article II:** An agentic perspective on socio-institutional rescaling: Institutional work for fostering residential electricity storages in Germany and the EU[15]

Abstract. The debates over multi-scalarity and rescaling are receiving increasing attention in transition studies. This paper focuses on socio-institutional rescaling. Taking on an agentic perspective on rescaling, the case study explains how actors engage in institutional change processes across scales with the intention to strengthen an industrial path. The concrete activities for rescaling are operationalised by means of the concept of institutional work. The paper further investigates impeding and enabling conditions therefore. Our conceptual elaborations are illustrated by in-depth interviews and participant observation of industry associations in the market for residential storage systems in Germany. The findings reveal that particularly German industry associations and companies engage in institutional work at a national and EU scale fostering the national implementation of EU legislation and affecting legislation, discourses and standards at a European scale. While institutional semi-coherence is found as a constraining condition for socio-institutional rescaling, holding positions at multiple scales enhances agency.

6.1 Introduction

A key question in transition studies is how new technological solutions or modes of consumption and production challenge established, often rigid and inert socio-technical systems (Markard et al. 2012; Geels 2002). The rigidity of these systems is usually attributed to the presence of socio-technical regimes, which consist of highly institutionalised formal and informal rules that have co-evolved with technologies and actor-networks (Markard & Truffer 2008; Kemp et al. 1998). The evolvement of such regimes has traditionally been analysed mainly within nation states, often followed up by global regime changes. Embedded in national regimes, niches have been conceptualised as local, geographically confined phenomena, which cumulate and upscale for finally challenging regimes (Miörner & Binz 2021).

Recent contributions have developed a more nuanced understanding of multi-scalar niche-regime interactions that are the result of dynamics playing out in various places and at different levels of governance (Madsen 2022a; Miörner & Binz 2021; Binz et al. 2020; Fünfschilling & Binz 2018). Hence, regimes and niches cannot be self-evidently attributed to the global, national or local scale. Instead, socio-economic structures at different spatial scales and in various places influenced by temporal dynamics and sector-specific characteristics have to be taken into account (Miörner & Binz 2021; Fünfschilling & Binz 2018; Truffer & Binz 2017; Binz et al. 2016; Wieczorek et al. 2015; Raven et al. 2012; Coenen et al. 2012). Whereas, for instance, the water sector might be shaped by a very strong global regime structure, the energy sector shows considerable spatial variation in spite of transnationally acknowledged targets towards decarbonisation (Fünfschilling & Truffer 2014; MacKinnon et al. 2019; Markard 2018; Ćetković & Buzogány 2016).

[15] The article has been resubmitted to the Journal *Environmental Innovation and Societal Transitions* after having received the first reviewers‘ comments. Thus, this text is the one-time reviewed and revised version. The paper has been co-authored by Markus Grillitsch, Lund University, Sweden, and Hans-Martin Zademach, Catholic University of Eichstätt-Ingolstadt, Germany. I was the lead and corresponding author for this paper. The co-authors made valuable contributions in conceptualising and reviewing the paper.

A multi-scalar view on institutionalisation particularly holds potential for explaining strategic agency seeking to hinder or promote transitions. As regimes are based on semi-coherent institutional rationales that are continuously challenged and reinforced, it becomes crucial to focus on the diffusion of niche and regime rationales across space beyond their place of origin (Bauer & Fünfschilling 2019; Fünfschilling & Binz 2018; Sengers & Raven 2015), but also across scales (Madsen 2022a; Miörner & Binz 2021). The latter requires shedding light on how actors rescale institutional field logics, technical practices or core values, which is referred to as rescaling (Miörner & Binz 2021). While shifts in power dynamics (Madsen 2022a), actor types (Roebke et al. 2022; Miörner & Binz 2021; Kivimaa et al. 2019), actors' networks (Fünfschilling & Binz 2018; Bauer & Fünfschilling 2019) or types of transition trajectories (Miörner & Binz 2021) have been the subject of recent research, this paper focusses on the agentic dimension of rescaling.

In doing so, we draw on the notion of socio-institutional rescaling, which refers to the (un)structuration of informal and formal institutions and the (dis)integration of social practices (Grillitsch et al. 2025). Actors' activities and strategies for socio-institutional rescaling are operationalised by means of institutional work (Lawrence & Suddaby 2006). Based on critical realist underpinnings, we start from the premise of an existing scalar arrangement along with scalar barriers and opportunities for change that shape the purpose and possibilities of actors. Hence, we raise the following research questions: *How and why do actors engage in socio-institutional rescaling with the intention to foster transitions? Which actors engage at which scale in rescaling institutional rationales?* For taking account of the structural context the actors are embedded in, we aim at shedding light on the question of *what are enabling or impeding conditions for such institutional work.*

Empirically, we provide new original insights from the market for residential storage systems in Germany and at EU level. As will be shown, this market presents a suitable case for analysing socio-institutional rescaling, since actors at the national and European scale, such as industry associations or electricity providers, engage in institutional work activities across scales in order to induce regulatory changes, enforce standards or shape the narrative around this technology.

The remainder of the paper is structured as follows. The next section presents the conceptual background of our study. After introducing our research design and case (section 6.3), we elaborate on the configuration of residential storages in Germany and at EU level with a particular focus on the institutional context. We further present institutional work activities for socio-institutional rescaling and identify scalar conditions enabling or constraining rescaling activities (section 6.4). In section 6.5, we discuss relevant actors and institutional work activities, scalar conditions impeding and fostering rescaling as well as a relational perspective on rescaling. Section 6.6 concludes by discussing limitations of this study and future research lines.

6.2 Towards an analytical framework for investigating the agentic dimension of socio-institutional rescaling

Based on scale research in geography and sustainability transitions (6.2.1), section 6.2.2 zooms in on socio-institutional rescaling and elaborates on the concept of institutional work for operationalising agency. Drawing on these key concepts, we then outline the research questions applied to analyse socio-institutional rescaling along with the scalar barriers and opportunities for agency (6.2.3).

6.2.1 Scale and rescaling in human geography and transition studies

Scale and rescaling represent core categories of geographic theorising (Binz et al. 2020; Hansen & Coenen 2015; Murphy 2015), with two main perspectives being prominent, the political economy perspective and post-structural approaches (Grillitsch et al. 2025; MacKinnon 2010). The political economy perspective refers to scale or more pointedly scalar arrangements as an outcome of social construction and material expression of wider social, political, economic and cultural developments (Brenner 1998; Swyngedouw 1997; Smith 1993). Accordingly, scale is conceptualised as continuously produced, contested and restructured by actors, instead of being a fixed, ontologically given container associated with inherent characteristics and a specific size or level, such as 'the region' or 'the nation' (Swyngedouw 2004; 1997). Since actors then establish, differentiate, hierarchise and reorganise multi-level spatiality, scalar transformations have to be approached relationally stressing mutual formative interactions (Brenner 2001; Howitt 1993). Thus, scales and scalar arrangements are understood as the outcome of social and political contestation taking place between actors, but at the same time as progenitor for further social processes (Swyngedouw 2004, 1997; Smith 1993).

Post-structuralist scholars have criticised this perspective for a tendency to overemphasise 'vertical' and, thus, hierarchical links between territorially defined scales, such as local, regional, national, global, and for reifying and essentialising scales (Jones et al. 2017; MacKinnon 2010; Leitner & Miller 2007). By contrast, the post-structural perspective understands scale as institutionalised, but always emergent sets of practices and discourses, whose significance or importance depends on the context and situatedness of the actors participating in these practices and discourses. Refusing any kind of hierarchy, rescaling would happen in a flat array of socio-spatial relations rearranging differently scaled sets of routines, power dynamics and discourses (Grillitsch et al. 2025).

Intending to blend elements of both strands, MacKinnon (2010) argues for investigating the processes through which the relevant scale is determined rather than scales themselves. Writing from a critical realist perspective, he suggests integrating discursive and material dimensions. Hence, he considers scale as a dimension of strategic agency aiming at influencing both discursive and material aspects in order to privilege some scales over others and, thus, exert influence and control over specific areas of societal life and public policy. Inspired by MacKinnon (2010), this article adopts a middle-ground position incorporating both material and discursive dimensions.

Recent contributions in transition studies have addressed multi-scalarity. At a most generic level, a multi-scalar perspective rejects the idea of niches being local, geographically confined phenomena. Instead, niches and also regimes are understood as the result of dynamics playing out in various places and at different levels of governance (Miörner & Binz 2021; Binz et al. 2020; Fünfschilling & Binz 2018). Hence, conceptualising transition trajectories is not a question of distinguishing 'global' regime and niche structures from various 'national' and 'local' variants thereof. On the contrary, taking account of socio-economic structures at different spatial scales and in various places influenced by temporal dynamics and sector-specific characteristics is required (Miörner & Binz 2021; Fünfschilling & Binz 2018; Truffer & Binz 2017; Binz et al. 2016). For example, as mentioned above, while the water sector is shaped by a strong global regime, the energy sector is characterised by considerable spatial variation (MacKinnon et al. 2019; Markard 2018; Fünfschilling & Truffer 2014; Ćetković & Buzogány 2016).

This paper takes on a multi-scalar perspective on institutionalisation. Drawing on the notion that regimes are based on semi-coherent institutional rationalities that are continuously challenged by alternatives, we need to focus on how niche and regime rationalities diffuse across space (Bauer & Fünfschilling 2019; Fünfschilling & Binz 2018; Sengers & Raven 2015), but also across scales. The latter is referred to as rescaling by Miörner and Binz (2021) who shed light on how actors rescale institutional field logics, technical practices or core values from their immediate local, regional, national or trans-local contexts into regime structures at higher scales and vice versa. Madsen (2022a) views rescaling as process of shifting policies and politics from one scale to another, potentially including changes in power and control over the system. Thus, some (regime) actors may be empowered, whereas other (niche) actors are disempowered.

Unpacking the different dimensions of rescaling, Grillitsch et al. (2025) disentangle three theoretically distinct but interrelated scalar dimensions: spatio-temporal, socio-institutional, and techno-economic. Spatio-temporal rescaling captures how economic relationships expand or contract in space and time (Asheim 2020; Martin & Sunley 2022). Socio-institutional rescaling refers to the (un)structuration of informal and formal institutions and the (dis)integration of social practices (Miörner & Binz 2021; Fünfschilling & Binz 2018). Techno-economic rescaling means changes in the scale of economic activities also including economies of scale (Wadley 2021). This is based on the choices made by and available to economic actors and the direction of technological development. These three dimensions play together. For example, while the era of globalisation was characterised by free trade agreements, the new phase of industrial policy is driven by three factors, namely geopolitics and security risks, climate and environmental change, and rising inequalities caused by deindustrialisation and the offshoring of manufacturing jobs. Thus, new policies (e.g., the US Inflation Reduction Act of 2022) may imply a socio-institutional rescaling of policymaking towards the national scale, while also aiming at spatio-temporal rescaling (reshoring or relocating economic activities to countries considered as political allies) or techno-economic rescaling (substituting cheap labour with other forms of production).

Acknowledging the role of actors in rescaling, Grillitsch et al. (2025, 5) defined rescaling as *"an agentic process in which multiple sets of actors engage with the aim to change the rationales and conditions underlying the structuring of economic relationships, and the intended and unintended consequences of this engagement".* Thus, rescaling is a form of change agency, which is future-oriented and aimed at an outcome, which is expected to be more desirable than the current state (Emirbayer and Mische 1998). For example, rescaling may aim at tackling inadvertent repercussions of globalisation, such as environmental and social harm, value chain insecurities and geopolitical tensions (e.g., European Green Deal or the Inflation Reduction Act in the US). The possibilities of actors to engage in rescaling processes, however, are shaped by these historically developed structures in the sense of institutions, economic relations and uneven power relations (Mackinnon 2010; Grillitsch et al. 2025). In this paper, we zoom in on socio-institutional rescaling and the interplay between scalar institutional arrangements and agency.

6.2.2 Institutional work as driver for socio-institutional rescaling

Socio-institutional rescaling refers to a reconfiguration of institutional patterns and relations through processes of (de-)institutionalisation (Fünfschilling 2019; Fünfschilling & Binz 2018). Such socio-institutional rescaling can be triggered by differing core value propositions across

scales, ranging from economic growth to societal and environmental values, such as sustainability, which might lead to frictions and institutional complexity. Socio-institutional rescaling can be understood as a horizontal and/or vertical structuring. The horizontal dimension concerns societal, sectoral, industrial or organisational scales. For instance, rescaling might shift activities from the public to the private scale. The vertical dimensions refers to a spatial hierarchy (local – global). For example, the relevance of the national scale is subject of much debate (Grillitsch 2025). While, on the one hand, international organisations (e.g. the World Bank, WHO) increasingly shape the diffusion of sustainable technologies internationally (Miörner & Binz 2021; Fünfschilling & Binz 2018), the revival of industrial policy in the US and Europe and the intend to decouple value chains, on the other hand, suggests a shift in scale from the global level to trading blocs or nations (Aiginger & Rodrik 2020).

This paper focusses on the vertical dimension of scalar arrangements. Corresponding to critical realist MacKinnon (2010), we take established scalar arrangements, which can be known through socially mediated concepts and representations, as a starting point. In this context, we scrutinise actors' strategies to shape the scalar rationales and boundaries according to their political agenda. In doing so, we take on a relational perspective as actors *"tend to privilege some inherited scales over others and reshape inherited scalar arrangements in line with their ideology and sociopolitical outlook"* (MacKinnon 2010, 31). According to Grillitsch et al. (2025), we argue that the structures, in which the actors are embedded, shape the purpose and possibilities to change this scalar arrangement. In our case, these structures mainly refer to the scalar institutional arrangements. For example, supportive policies and standards, narratives or networks, the potential for interaction and the lack thereof can have a hindering or beneficial effect on rescaling.

As regards investigating these interactions between inherited scales and emergent social activities, MacKinnon (2010) foregrounds actors' routines, practices and networks. Correspondingly and given our focus on socio-institutional rescaling, we draw on the concept of institutional work (Lawrence et al. 2009; Lawrence & Suddaby 2006). The Institutional work-framework serves as lens that operationalises micro-level activities in attempts to induce institutional changes. This concept has increasingly been featured within transition studies (e.g., Löhr et al. 2022; Kivimaa et al. 2021; Becker et al. 2021; Kainiemi et al. 2020; van Doren et al. 2020; Duygan et al. 2019) in order to elucidate actors' possibilities to (re)produce institutional environments and overcome the structure-agency paradox (Fünfschilling & Binz 2018; Sotarauta & Pulkkinen 2011; Battilana et al. 2009).

Lawrence and Suddaby (2006) identified distinct practices of institutional work: While some activities aim at the creation of institutions by developing rules as well as rewards and sanctions enforcing that rules (e.g., *advocacy, educating, changing normative associations with novel innovations*), the maintenance of institutions requires ensuring compliance with existing institutions (e.g., by *policing* or *deterring*). Practices aiming at the disruption of institutions undermine the compliance of actors with institutions by making them less attractive and delegitimising them (e.g., by *officially changing rewards and sanctions*; see Appendix H for a full list of the original institutional work types by Lawrence and Suddaby 2006).

On a more general level, Lawrence and Suddaby (2006) depicted two main forms of work: first, activities aiming at the mobilisation of resources, such as political power, money, knowledge or social capital, for establishing regulations, securing knowledge through patenting or establishing networks with powerful actors, and, second, efforts targeting the (de-)construction of rationales for shaping discourses and, thus, (de-)legitimising an innovation (Fünfschilling &

Truffer 2016). Taking scale-based discourses into account proves advantageous for a critical realist approach towards scales.

6.2.3 Analytical framework for investigating socio-institutional rescaling activities

From this discussion, *w*e focus on actors' activities and strategies for socio-institutional rescaling operationalised by means of institutional work (IW, Fig. 11). Drawing on critical realist underpinnings, we start from the premise of an existing scalar arrangement along with scalar barriers and opportunities for change that shape the purpose and possibilities of actors. Based on the relational perspective of scale, we suggest that actors not only affect scalar rationales and conditions, but also influence the relevance of scales.

Hence, we address the following research questions: *How and why do actors engage in socio-institutional rescaling with the intention to foster transitions? Which actors engage at which scale in rescaling institutional rationales?* For taking account of the structural context the actors are embedded in, we aim at shedding light on the question of *what are enabling or impeding conditions for such institutional work.*

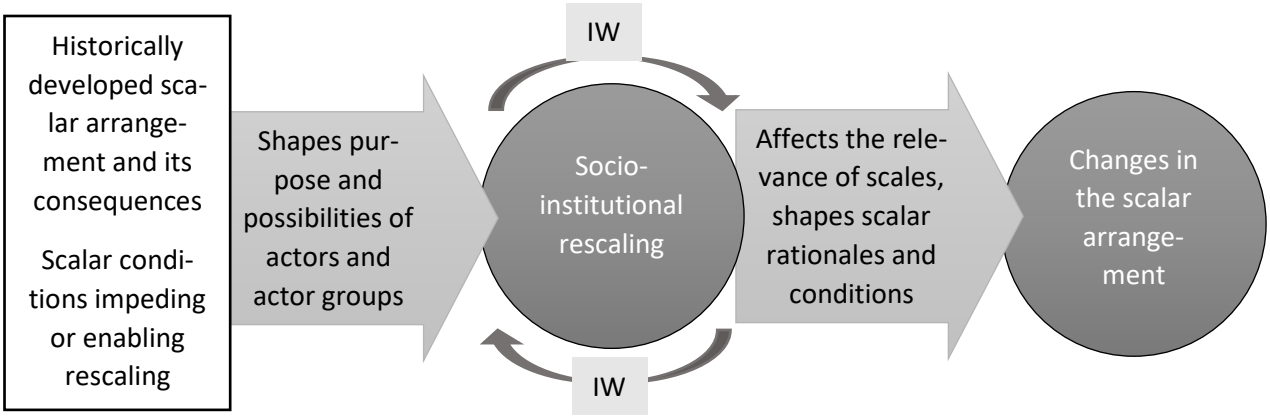


Figure 11: Conceptual framework for socio-institutional rescaling.
Source: Author's elaboration.

6.3 Case selection, methods, and data

In order to gather in-depth insights on the concrete activities for socio-institutional rescaling, we conduct a qualitative case study (Yin 2014; Eisenhardt & Graebner 2007). In the following, we first provide an overview of the selected case, before describing data collection and analysis.

6.3.1 Case selection: the market for residential storage systems in Germany and the EU

This case study covers business models involving residential storage systems with a maximum capacity of 30 kWh in Germany. Dating back to the 2000s, the market for residential storage systems in Germany showed rising sales figures, thus, being the largest in Europe (in absolute terms in 2023, ees Europe 2024). The initially most common use case has been the so-called prosuming (a terminological hybrid of *pro*ducer and con*sumer*): Combined with photovoltaics, the storage systems allow for enhancing self-production and self-consumption of electricity in

private households by storing surplus energy beyond current consumption (Figgener et al. 2020; Tepe et al. 2021; Kairies et al. 2019). Since then, further business models have been developed. Residential storage is part of private energy management systems (smart homes), which facilitate demand side flexibility by connecting electrical loads (storages, heat pumps, electric vehicles, etc.) and producers (typically photovoltaics). Furthermore, third party aggregators digitally connect large numbers of photovoltaic and battery systems into so-called virtual power plants. Thus, the storage systems can be controlled remotely in order to provide grid services such as frequency containment reserve, i.e. variations of mains voltage are balanced through storing or withdrawing power during times of electricity interruption or overproduction (Becker et al. 2024; Sousa et al. 2019). Moreover, the virtual power plants can take advantage of price volatility in international electricity trade through timed electricity sales. Another use case are so-called energy communities enabling members to sell and buy electricity from other peers depending on their current demand or surplus production (Blasch et al. 2021; Mlinarič et al. 2019).

As regards our perspective on scales, residential storages in Germany constitute a telling case, as the market is characterised by a preexisting scalar arrangement, which is subject to institutional work carried out by business stakeholders. More concretely, our empirical material suggests taking the national as well as the EU level into account[16]. Considering regulation, the provision of electricity is by far a national affair, which is also reflected by earlier case studies (Bauer & Fünfschilling 2019; Lauber & Jacobsson 2016; Strunz 2014; Verbong et al. 2013). However, advocates of residential storage systems (e.g., industry associations, storage manufacturers and electricity providers) regard regulation in Germany as key obstacle to a more profitable realisation of business models involving storage systems beyond the above mentioned self-consumption due to, for instance, fees and charges or complex metering requirements (see blinded reference[17]). Since EU legislation is concerned with residential storage systems and needs to be transposed to a national level, agents also make active use of the EU scale when engaging in institutional work for improving the conditions of residential storages in Germany. The relevance of EU legislation and policy targets is reinforced by current political events (energy crisis) and by materiality given liberalised European electricity markets. Thus, the German case is very suitable for analysing how actors engage in institutional work in order to shape the rationales and boundaries of a scalar arrangement according to their political agenda.

6.3.2 Data collection and analysis

The empirical analysis draws on desk based research of secondary data, participant observation and qualitative interviews. Desk based research (e.g., market data, reports of utilities, ministries and industry associations, company websites and legal texts) enriched our knowledge about current institutional developments at a national and EU scale. We further draw on participant

[16] The actors at the states scale in Germany (*Bundesländer*) also turned out to mainly advocate residential storage systems (mainly due to resident companies and projects as well as local resistance to grid expansion). However, sector experts consider governing the electricity system largely a national affair without relevant decision-making power at the states level. The main legislative acts do not require the approval of the Federal Council (*Bundesrat*). On a European scale, the Bundesländer maintain permanent representations. Notwithstanding, our empirical material suggests that these representations are not really involved in institutional work activities. Instead, they act as intermediaries delivering information from the national or state scale, but rather upon request than on their own initiative.

[17] This reference refers to Zademach and Käsbohrer (2022).

observations during 42 working group meetings of a German industry association in the electricity system, which included 45-minute to daylong events and provided valuable context information on regulatory amendments and industry stakeholders' reactions (see Appendix I). The association's members are mostly affiliated with the national scale electricity sector (e.g., electricity providers, Distribution System Operators (DSO), storage manufacturers).

32 semi-structured interviews with national energy sector experts and industry leaders, ranging from academics, government officials and lawyers to representatives of utilities, industry associations and DSOs, were conducted (see Appendix J). The first interview partners either were members of the aforementioned industry association or identified through desk-based research, whereas further experts were sampled based on recommendations from those interviewed (snowball method). The relatively large share of regulators and industry associations is due to the fact that regulation constitutes the main barrier for the further diffusion of residential storages in Germany. In this context, industry associations are the main player in advocating regulatory changes. In the same way, ten EU level actors were identified (representatives of EU institutions, industry associations, NGOs, corporate representations, consultancies) who were considered relevant agents for rescaling. At both scales, we consciously got back to actors who initially refused to do an interview due to a lacking contact with residential storage systems. In doing so, we aimed at finding mechanisms and conditions for a missing engagement. All interviews were conducted by phone or videoconferencing between February 2021 and November 2023 and lasted about 60 minutes on average. All but five interviews were recorded and transcribed verbatim. Extensive notes were gathered in the unrecorded ones.

We asked our interview partners about the scalar arrangement around residential storages at a national and EU scale, which is favourable for or impeding the diffusion of residential storage systems (e.g., supportive/hindering policies, standards, the market size of the technology). Furthermore, we focused on institutional work practices for rescaling. At this point, the coding scheme was informed by theory-led expectations (Lawrence and Suddaby 2006), while also allowing for case-specific nuances. In addition, we asked for scalar conditions enhancing or impeding these institutional work activities (e.g., the potential for interaction, narratives and expectations). The empirical material was subject to a qualitative content analysis (Siggelkow 2007; Mayring & Fenzl 2019, for exemplary quotes see Appendix K). The agency of actors as an emergent property of interacting individuals is hard to identify, but indicated by the extent of influence their institutional work had on changing relevant regulation as well as narratives, which we assessed through actual decision- and policy-making interventions as well as cross-validated statements about the estimated impact (Sotarauta & Grillitsch 2023).

6.4 Findings

We start the findings section by explaining the given scalar arrangement, in other words, the socio-technical configuration around residential storages in Germany and at EU level with particular focus on the institutional context and, thus, potential for socio-institutional rescaling (section 6.4.1). Section 6.4.2 presents institutional work activities for socio-institutional rescaling. In section 6.4.3, we reveal scalar conditions enabling or constraining rescaling activities.

6.4.1 Scalar arrangement in the market for residential storage systems in Germany and the EU

As regards the actors related to the configuration around residential storage system, storage manufacturers and green electricity providers pioneered this market introducing first business models. Eventually, also conventional electricity providers launched business models involving residential storage systems (e.g., E.On Solarcloud). More recently, automobile sector actors advanced into the electricity system providing electric vehicles along with residential storage systems for private charging and even electricity contracts. Both automobile and electricity sector actors share a common storyline of a prosumer-driven decentral electricity provision.

Socio-institutional rescaling resulting in growing sales numbers has been initiated by broader developments. First, relatively high electricity prices and declining feed-in tariffs for solar power led to financial savings when using battery systems for self-consumption. Second, end consumer prices for storage systems were declining due to technical advances in terms of materials, life spans and capacities as well as economies of scale resulting from the growing electric vehicle market. Third, a wish to contribute to the energy transition and individual autarky, especially in light of the emerging energy crisis, were compelling motivation for many people, potentially already owning photovoltaics. Lastly, the growing relevance of e-mobility led to further opportunities, for instance, increasing the share of self-consumption through vehicle charging at home.

However, the configuration around residential storage systems, in other words the realisation of further business models, is to some extent in conflict with energy regulation in Germany, which calls for further socio-institutional rescaling. German energy regulation mainly consists of the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) and the Energy Industry Act, (Energiewirtschaftsgesetz, EnWG). While this legal environment allows for prosuming, fees and charges, very complex metering requirements and grid connection procedures (still) hamper the economically feasible realisation of other abovementioned business models. This applies, for example, to energy communities involving energy sharing and the provision of frequency containment reserve (see Tab. 7/8). One of the main reasons is the mandatory separation of green and conventional grid power leading to complex metering requirements since the different electricity flows are associated with different subsidies, taxes and fees respectively (§ 19 EEG). Consequently, our empirical material suggests that the large part of residential storages is only used for prosuming.

This regulatory framework is mainly shaped by the Federal Grid Agency (BNetzA) and the Ministry for Economic affairs and Climate action (BMWK).[18] Our empirical material reveals

[18] As regards amending the central policies, the German federal parliament is in formal decision-making power over energy policy. The BMWK is in charge of substantively developing the legislation. However, although being intended as downstream, executive authority, considerable power over legislation also lies with the BNetzA

an often reluctant or critical attitude towards residential storage systems in BMWK and BNetzA. The arguments against storage systems are usually of a technocratic nature. For instance, in 2021, a BNetzA representative emphasised that residential storages hamper households' predictability and controllability. Furthermore, the interviewee questioned their need and profitability and rather pleaded in favour of a full feed-in of self-produced electricity, drawing on the arguments of following market signals in an efficient way and of a true-cost pricing of net electricity with grid fees, since electricity has to be fully available at any time in spite of residential storage systems.

Thus, actors favouring residential storages (mainly businesses and industry associations) consider the German institutional environment in terms of regulation and narratives as hindering the further diffusion of the technology. Therefore, they engage in navigating and leveraging institutions, also at a higher level, namely the EU, since EU legislation needs to be implemented in the member states.

The EU agenda setting, decision-making and legislation is commonly agreed on being characterised by a multi-level governance logic.[19] This means, member states share power in producing and implementing legislation mainly with the Commission, Council and Parliament[20] (EU 2024a, 2024b; Appendix L describes the main decision-making institutions in more detail). EU-level and national industry associations, consultancies, NGOs, and corporate representations are further actor types with strong agency in shaping legislation and discourses by means of institutional work (see also 6.4.2).

As regards EU legislation concerned with residential storages, the 'Renewable Energy Directive' (REDII) and the 'Directive on common rules for the internal market for electricity', commonly referred to as 'Electricity Market Directive' (European Commission 2024a, 2024b; Directive 2023/2413; Directive 2019/944) are most relevant.[21] In the field of energy, most legislation is by directive[22], which sets out binding targets, but allows for leeway in enforcing these goals, i.e. member states are instructed to devise their own legislation and measures in order to

providing extensive advisory services to the ministry, and even developing draft laws on their own account due to a high level of expertise and commitment.

[19] The EU governance system is commonly referred to as multilevel governance logic, although specific levels of action might reflect different logics. For instance, concerning the European Council and the Council of Ministers, the logic of action tends towards being intergovernmental, whereas in the Commission, the Parliament and the Court, a more supranational logic is prevalent (Bache 2012; Jordan 2001; Hooghe & Marks 2001; Marks et al. 1996). Multilevel governance means the dispersion of authority (understood as the competence and legitimation to make binding decisions) across scales, i.e. to self-ruled regional jurisdictions as well as to supranational institutions (Hooghe & Marks 2021, 2023; Hooghe & Marks 2001).

[20] In order to adopt EU legislation, inter-institutional negotiations have become standard practice, which generally take the form of tripartite meetings ('trilogues') between the Parliament, Council and Commission. Based on proposals submitted by the Commission, the Parliament and Council adopt their positions and designate negotiators (such as the rapporteur for the Parliament or representatives of the Council's presidency). In the trilogues, the Parliament and Council debate, while the Commission acts as a mediator facilitating an agreement between the co-legislators. Any provisional agreement reached in trilogues is informal and needs to be approved in the Council and mostly also in the Parliament (except for special legislative procedures, see also Appendix L). The European Council is a further part of agenda setting with respect to the EU's overall direction and political priorities (EP 2024; EUCO & CoM 2024; EU 2024a, 2024b).

[21] In addition, residential storage systems are touched upon in the 'Energy Efficiency Directive' and the 'Energy Performance of Buildings Directive', and in the 'Commission Recommendation on Energy Storage' of 2023 (Directive 2023/1791; Directive 2010/31/EU; Recommendation 2023/C 103/01).

[22] Different types of legal acts have to be differentiated, regarding whether they are binding or not, as well as whether they are affecting all EU countries or just a few (regulations, directives, decisions, recommendations, opinions) (EU 2024c).

reach the targets (Hooghe & Marks 2023; EU 2024c). The Renewable Energy Directive and the Electricity Market Directive are concerned with rules facilitating decentral self-consumption and energy communities claiming, for instance, a distinct legal role for energy storages and the abolishment of double fees and charges, of bureaucratic barriers and inadequate measurement requirements. Thus, interviewees, mainly national industry associations, point to contradictions to German regulation in some points, although a consistent implementation is required (see again Tab. 7/8 and Appendix M for a more detailed description of contents).

In this context, there are diverging perceptions about the legislation's impact on the member states level. Whereas both EU-level (e.g., Commission representatives) and national actors promoting home storages (industry associations, companies) welcome the directionality of EU legislation, national authority representatives, but also EU-level industry associations and consultancies, rather allege the directives' leeway of implementation into national regulation, the missing level of detail in legislation on residential storages, and the Commission's lack of manpower for revising the legislation. A national ministry representative even points to contradicting pieces of EU legislation regarding grid fees or the legal definition of energy storage.

As regards discourses and narratives, EU-level interviewees emphasise the high attention for and legitimacy of prosuming and storing energy. Especially energy communities are considered a prominent theme (which potentially, but not necessarily can be complemented by storage systems). Nonetheless, respondents regard residential storages rather a niche due to their little prominence in legislation, the high prices of residential storages, and the small market and installed capacities at a European level. The Commission and Parliament underline the policies' technology neutrality. Furthermore, interviewees highlight the focus on EV batteries and bidirectional charging, hydrogen applications and larger-scale storage projects stabilising grids.

Taken together, national actors see possibilities to engage at the EU level to change narratives at a higher scale in support of residential storages, and ideally realise a more detailed regulation at the EU level, which would then feed-back and affect narratives and regulations at the German level as well as in other EU countries, enlarging the market potential and characterising an upward-downward and sidewise (between EU countries) socio-institutional rescaling. In the following, we elaborate on their concrete activities.

Table 7: Main regulatory requirements in EU legislation ('Renewable Energy Directive' REDII, 'Electricity Market Directive'), regulatory barriers in EEG 2017 and the respective changes through recent amendments in 2021 and 2023 relevant for business models.

EU legislation (RED II and Electricity Market Directive)	Main regulatory barriers in EEG 2017	Changes in EEG 2021	Changes in EEG 2023
Bureaucratic barriers: **RED II: Art. 21, 2:** renewables self-consumers, individually or through aggregators, are entitled (a) to generate, consume, store renewable energy and sell their excess production, including through electricity suppliers and peer-to-peer trading arrangements without discriminatory or disproportionate procedures and charges. **Electricity Market Directive: Art. 15, 1:** final customers are entitled to act as active customers without being subject to disproportionate or discriminatory technical requirements, administrative requirements, procedures and charges […]. **Art. 15, 5:** Active customers owning an energy storage facility (a) have the right to a grid connection within a reasonable time after the request, provided that all necessary conditions (e.g., balancing responsibility, adequate metering) are fulfilled; […] (c) are not subject to disproportionate licensing requirements or fees.	*Installation of photovoltaics and storage systems highly complex bureaucratically.*	Easier grid access for storage systems (§8 Abs. 5 S. 3 EEG).	
Double charges: **RED II: Art. 21, 2b**: renewables self-consumers, individually or through aggregators, are entitled […] to install and operate electricity storage systems combined with installations generating renewable electricity for self-consumption without liability for any double charge, including network charges, for stored electricity remaining within their premise. **Electricity Market Directive: Art. 15, 5:** Active customers owning an energy storage facility (b) are not subject to any double charges, including network charges, for stored electricity remaining within their premises or when providing flexibility services to system operators.	De-facto double charging with grid fees, taxes and (EEG-) surcharges for installations > 10 kWh in the course of storing and withdrawing electricity from the storage (grid services) due to high and complex measurement requirements (§§ 60, 61l EEG). Regarding EEG-surcharge, in any case 40% each time for storing and withdrawal of electricity (§ 61b EEG).	§ 61l EEG simplified, grid services involving storing and withdrawing electricity from the storage possible for prosumers without double charging with taxes and (EEG-) surcharges. *However, not applied to grid fees and still highly complex in terms of measurement requirements.*	Suspension of EEG surcharge (§ 58 EEG). Simplified measurement at grid connection point (behind-the-meter): most fees and taxes only relate to withdrawals from and feed-ins of electricity to the grid, balancing of electricity flows (acc. to §21 EnFG 'Energiefinanzierungsgesetz', former § 61l EEG). *However, still contested: grid fees and electricity taxes in multi-use applications.* Storage losses are exempt from charges and fees (§ 21 EnFG).

EU legislation (RED II and Electricity Market Directive)	Main regulatory barriers in EEG 2017	Changes in EEG 2021	Changes in EEG 2023
Threshold for exemptions of charges and fees: **RED II**: **Art. 21, 3:** Member States may apply non-discriminatory and proportionate charges and fees to renewables self-consumers if (a) the self-generated renewable electricity is effectively supported via support schemes, (b) if the total installed electrical capacity of installations is more than 30 kW.	Threshold for total exemptions of grid fees, taxes and (EEG-) surcharges at 10 kWh (§ 61a Nr. 4 EEG)	Threshold for exemptions of grid fees, taxes and surcharges set from 10 kWh to 30 kWh for new and existing installations (§ 61 Abs. 1 EEG).	
Rules on energy communities: **RED II: Art. 22, 1:** final customers, in particular household customers, are entitled to participate in a renewable energy community while maintaining their rights or obligations as final customers, and without being subject to unjustified or discriminatory conditions or procedures preventing their participation in a renewable energy community. **Art. 22, 2:** renewable energy communities are entitled to produce, consume, store, sell and share renewable energy and to access all suitable energy markets both directly or through aggregation in a non-discriminatory manner. **Art. 22, 3:** member states shall carry out an assessment of existing barriers and potential of renewable energy communities **Art. 22, 4:** member states shall provide an enabling framework to promote and facilitate the development of renewable energy communities addressing, inter alia, unjustified regulatory and administrative barriers to renewable energy communities, the possibility to provide aggregation or other commercial energy services, the relevant DSO to facilitate energy transfers within communities, that renewable energy communities are subject to fair, proportionate and transparent procedures, including registration and licensing procedures, and cost-reflective network charges, as well as relevant charges, levies and taxes, ensuring that they contribute, in an adequate, fair and balanced way, to the overall cost sharing of the system in line with a	*Rules on energy communities not implemented.*		

EU legislation (RED II and Electricity Market Directive)	Main regulatory barriers in EEG 2017	Changes in EEG 2021	Changes in EEG 2023
transparent cost-benefit analysis of distributed energy sources developed by the national competent authorities.			
Self-consumers located in the same building: **RED II: Art. 21, 4:** Member States shall ensure that renewables self-consumers located in the same building, including multi-apartment blocks, are entitled to engage jointly in activities referred to in paragraph 2 and that they are permitted to arrange sharing of renewable energy that is produced on their site or sites between themselves, without prejudice to the network charges and other relevant charges, fees, levies and taxes applicable to renewables self-consumers.	Joint production and usage of renewables by self-consumers located in the same building hampered by regulatory and bureaucratic requirements (§ 3 Nr. 19 EEG; §§ 21b Abs. 3, 23b EEG).	Joint production and usage of renewables by self-consumers located in the same building (landlord-to-tenant electricity) facilitated, as electricity can be delivered by a third party instead of the facility operator itself (§ 21 Abs. 3 EEG). Furthermore, higher government subsidies for projects in rental apartments (§ 48 EEG).	
Multi-use: **Electricity Market Directive: Art. 15, 2:** active customers are entitled (directly or through aggregation) to sell self-generated electricity, to participate in flexibility schemes and energy efficiency schemes, to delegate to a third party the management of the installations required for their activities (installation, operation, data handling and maintenance), to be subject to cost-reflective, transparent and non-discriminatory network charges accounting separately for the electricity fed into and consumed from the grid, to be financially responsible for imbalances they caused in the electricity system. **Art. 15, 5:** Active customers owning an energy storage facility (d) are allowed to provide several services simultaneously, if technically feasible	*Separation of green and conventional grid power as well as self-consumed and fed-in electricity flows, leading to complex metering of different electricity flows and hampering multi-use of storage systems (§ 3, Nr. 1 EEG; § 19 EEG, § 61l EEG)*		
Feed-in compensation for self-generated electricity: **RED II: Art. 21, 2:** renewables self-consumers, individually or through aggregators, are entitled (d) to receive remuneration, including, where applicable, through support schemes, for the self-generated renewable electricity that they feed into the grid, which reflects the market value of that electricity and which may take	Annually set feed-in tariffs for electricity produced by photovoltaics.	Introduction of regulation for pv systems older than 20 years (§ 3 Nr. 3a EEG; § 19 EEG).	New rates of feed-in compensations for prosumers completely and partly feeding in (involving self-consumption) with the latter being reasonably high and, thus, enhancing the installation of a storage system in addition to photovoltaics (§ 100 Abs. 4 EEG).

EU legislation (RED II and Electricity Market Directive)	Main regulatory barriers in EEG 2017	Changes in EEG 2021	Changes in EEG 2023
into account its long-term value to the grid, the environment and society.			

Source: Erneuerbare-Energien-Gesetz (EEG) in Bundesministerium der Justiz (2023d) and Clearingstelle (2025a,b,c); Directive (2019/944); Directive (2018/2001); Directive (2023/24133).

Table 8: Main regulatory requirements in EU legislation ('Renewable Energy Directive' REDII, 'Electricity Market Directive') and regulatory barriers in ENWG 2011 and the respective changes through recent amendments in 2021 and 2022 relevant for business models involving residential storages (still existing barriers in italics).

EU legislation (RED II and Electricity Market Directive)	Main regulatory barriers in EnWG 2011	Regulatory changes in EnWG 2021	Regulatory changes in EnWG 2022
Definition of energy storage: **Electricity Market Directive:** Definition of 'active customer' (Art. 2, 8; Art. 15), 'energy storage' (Art. 2, 59), 'energy storage facility' (Art. 2, 60)	Missing definition of 'energy storage' as well as mobile storages, instead treatment as consumer and generation facility (§ 3, Nr. 15 EnWG).		In 2023, new definition of energy storage as new category besides generation, transport and consumption (§3 Abs.15d EnWG). *However, one-year time limit to incorporate definition in main regulatory frameworks.*
Double charges: **RED II: Art. 21, 2b:** to install and operate electricity storage systems combined with installations genera-ting renewable electricity for self-consumption without liability for any double charge, including network charges, for stored electricity remaining within their premise. **Electricity Market Directive: Art. 15, 5:** Active customers owning an energy storage facility (b) are not subject to any double charges, including network charges, for stored electricity remaining within their premises or when providing flexibility services to system operators.	Double charges with grid fees and charges (§ 19 Abs. 2 EnWG, § 17f Abs. 5 EnWG 'offshore grid fee' § 48 EnWG 'concession fee'), double charges with grid fees (§ 118 Abs. 6 EnWG).	Fees and charges measured analogously to § 61l EEG. *However, not applied to grid fees (§ 118 Abs. 6 EnWG).*	

Source: Energiewirtschaftsgesetz (EnWG) in Bundesministerium der Justiz (2023c) and Clearingstelle (2025d,e,f); Directive (2019/944); Directive (2018/2001); Directive (2023/24133).

6.4.2 Institutional work for socio-institutional rescaling

At a national scale, the main agents engaging in institutional work are German industry associations, whose members range from electric utilities, DSOs, storage manufacturers to automobile companies. These industry associations *educate* their members about German and EU level legislation and potential effects on business models. Furthermore, they often collaborate in *normative networks* with other associations, law firms, research institutions, and companies, while monitoring and evaluating (draft) legislation and developing suggestions for regulatory changes. Their *political advocacy* mainly addresses ministries, the German Parliament, the German Federal Council, and the BNetzA, for instance, by means of press releases, position papers about draft laws or associations' hearings. In addition to criticising the high complexity in regulation and, thus, unfavourable conditions for SMEs, a very salient argument is an inconsistent implementation of EU legislation in Germany. Industry associations and companies accuse governmental authorities of deliberately circumventing EU legislation, arguing that many amendments (e.g., abolishing high measurement requirements, bureaucratic barriers and double grid fees, taxes and surcharges associated with self-consumption and multi-use applications, Tab. 7/8) required by binding EU targets have been delayed or not implemented at all. EU-level stakeholders, such as industry associations, consultancies, or NGOs, are usually not directly engaged in an influential manner in transposing EU legislation into national regulation.

At an EU level, the promotion of residential storage systems is particularly reached by spreading the narrative around the technology and by influencing legislative initiatives. As stated throughout all interviews, institutional work mainly targets the Commission and Parliament. Addressing the Council is regarded as being rather difficult due to the lack of public stakeholder consultations for legislative amendments and its composition of national ministries' representatives.

EU-level industry associations related to the electricity system (e.g., promoting storage technologies, solar or wind energy) carry out *political advocacy* targeting EU institutions and *educate* about regulatory barriers as well as the relevance of storage technologies for enhancing renewables. Since these EU-level associations pool national members (mostly associations and companies), they aim at developing political positions based on their members' opinions. However, their positions and targets vary a lot due to national differences in electricity generation (rather competitively or monopolistically organised), energy mixes (e.g., share of renewables), differences in grid structures (ownership, number of DSOs) and buildings stocks (suitability for PVs), in business models, and regarding the relevance of electrifying transport and heating. Thus, our empirical material indicates a rather abstract level of argumentation regarding residential storages. NGOs engaged in institutional work rather foster a reduction of energy consumption or pledge for integrating electric vehicle batteries into households' energy management systems and replacing residential storages in order to constrain resource extraction.

This encourages German stakeholders to engage in institutional work at EU level on their own account. Their aim is to induce institutional changes benefitting the market for residential storages systems, thus, also benefitting the national scale, since EU legislation needs to be transposed to national regulation. Mainly national industry organisations and companies found targeted working groups, hire consultancies or establish branch offices and representations in Brussels. Hence, these actors carry out *advocacy work* targeting primarily the Parliament and Commission. Collaborating in *normative networks* with other associations or competitors, they, for example, release position papers or participate in workshops or stakeholder consultations in

the course of legislative initiatives. Thereby, they spread the narrative of residential storages being a solution for grid issues in light of increasingly integrated renewables. Hence, the aim is to *change prevailing associations* with the technology. In this context, they *educate* about regulatory requirements, technical specificities and advantages of residential storages.

Furthermore, interviewees emphasise the relevance of *policing*[23], especially setting standards for metering and communication. A German initiative (*normative network*) is stated to promote a communication standard at EU level, which facilitates demand side flexibility by connecting electrical loads (storages, heat pumps, electric vehicles etc.) and producers (photovoltaics) in households' energy management systems. The standard is criticised for forcing competitors to adopt it instead of providing interoperability. Members of this initiative are device manufactures, also offering residential storages. The institutional work activities are summarised in Tab. 9.

Table 9: Main actors engaged in institutional work and impeding or enabling conditions therefore.

Main actors	Institutional work	Enabling (+)/impeding (-) conditions
National industry associations	*Educating* their members about German and EU level legislation and potential effects on business models	Holding positions at multiple scales (+)
	Constructing normative networks with other associations, law firms, research institutions, and companies	Holding positions at multiple scales (+)
	Political advocacy addressing national ministries, German Parliament, German Federal Council, and the BNetzA (e.g., press releases, position papers about draft laws or associations' hearings)	Holding positions at multiple scales (+)
	Political advocacy targeting primarily the EU Parliament and Commission (position papers, workshops or stakeholder consultations in the course of legislative initiatives)	Holding positions at multiple scales (+) Expected positive narratives (+) German market size (+) National perspective (+)
	Educating EU institutions about regulatory requirements, technical specificities and advantages of residential storages, thus, *changing prevailing associations*	Holding positions at multiple scales (+) Expected positive narratives (+) National perspective (+)
	Policing[23] by setting standards for metering and communication	Holding positions at multiple scales (+) Perceived relevance of standardisation (+) German market size (+)

[23] After rechecking this article, I concluded that the proposed category *policing* should actually be *defining*, according to the definition by Lawrence and Suddaby (2006). I will correct the error in the next revision of the article, after consulting with the co-authors.

Main actors	Institutional work	Enabling (+)/impeding (-) conditions
Companies (particularly electricity utilities often with representations at EU level)	*Political advocacy* addressing national ministries, German Parliament, German Federal Council, and the BNetzA (but rather as members in industry associations or in *normative networks* with other companies)	Holding positions at multiple scales (+)
	Political advocacy targeting primarily the EU Parliament and Commission (position papers, workshops or stakeholder consultations in the course of legislative initiatives)	Holding positions at multiple scales (+) Expected positive narratives (+) Expected transparency (+) German market size (+) National perspective (+)
	Educating EU institutions about possible consequences of EU regulation for national business models	Holding positions at multiple scales (+) Expected positive narratives (+) Expected transparency (+) German market size (+) National perspective (+)
	Policing[24] by setting standards for metering and communication	Holding positions at multiple scales (+) Perceived relevance of standardisation (+) German market size (+)
Smaller or SME companies (e.g., electricity utilities or storage manufacturers)	Membership in industry associations, otherwise not engaged in institutional work to a great extent at both scales	Lacking knowledge on regulation (-) Complex regulation at both scales (-) Lack of monetary or financial resources (-)
National level NGOs	Not engaged in institutional work to a great extent	-
EU level industry associations	*Political advocacy* targeting EU institutions (stakeholder consultations)	Institutional semi-coherence (-)
	Educating EU institutions about regulatory barriers as well as the relevance of storage technologies for enhancing renewables.	Institutional semi-coherence (-)
	Not engaged in institutional work to a great extent at a national level	Lacking knowledge on national regulation (-) Complex regulation at both scales (-) Expected reservations (-) Underestimated EU impact at a national scale (-)
EU level NGOs	Not engaged in institutional work to a great extent	Focusing rather on a reduction of energy consumption and resources instead of storages
EU level consultancies	Collaborating *(normative networks)* with associations, law firms, research institutions, and companies	Lacking knowledge on national regulation (-) Complex regulation at both scales (-)

Source: Author's elaboration.

[24] After rechecking this article, I concluded that the proposed category *policing* should actually be *defining*, according to the definition by Lawrence and Suddaby (2006). I will correct the error in the next revision of the article, after consulting with the co-authors.

Concerning the outcome of institutional work, amendments of EnWG and EEG between 2021 and 2023 resulted in changes in line with EU regulation fostering a more profitable implementation of business models. Among others, in 2021, the threshold for exemptions from fees and surcharges was raised from a storage capacity of 10 kWh to 30 kWh, in 2023, the EEG surcharge was completely suspended. However, as mentioned above, for instance, energy communities and grid services such as frequency containment reserve are still subject to complex bureaucratic and measuring requirements (see again Tab. 7/8).

There are divergent perspectives on the role of EU legislation along with institutional work in inducing these changes. Many interviewees, mostly industry associations, but also companies, attribute the beneficial amendments to institutional work emphasising inconsistencies with EU legislation. By contrast, particularly national governmental authorities highlight the lack of detail in EU legislation on residential storages. Other sector experts (e.g., industry associations) hold the high complexity of German regulation and the delayed introduction of digitally communicating smart meters also responsible for the unused potential of storages systems. While acknowledging the impact of institutional work, some interviewees attribute amendments in 2022 and 2023 (e.g., the suspension of the EEG-surcharge) to the newly introduced government at the end of 2021[25].

Regarding the EU level, agents at both scales consider efforts of German industry associations and larger companies at EU scale as increasing and highly legitimised. As regards recent legislative amendments, (especially) EU level actors regard the role of residential storage systems as rather stagnating, with the exception of standards for metering and data communication facilitating real-time data transfer between batteries, battery owners and third parties such as electricity market participants (Renewable Energy Directive Article 20a, Directive 2023/24133).

6.4.3 Scalar conditions shaping actors' purpose and possibilities for rescaling

Our empirical material reveals conditions impeding and enabling socio-institutional rescaling. Table 9 provides an overview of which conditions trigger or constrain the specific rescaling activities.

A first constraining factor lies in often very detailed national regulations. Thus, due to a lack of knowledge or capacity to get familiar with national regulations, EU-level stakeholders, such as associations, NGOs or consultancies, struggle to get directly involved in rescaling activities at the national scale, like reaching out to national ministries and fostering the implementation of EU directives. A potential further hindering aspect for direct engagement is the language barrier.

In a similar vein, EU level actors and representatives of national authorities emphasise the huge number and high level of detail in EU dossiers affecting various national authorities. Due to the required capacity and coordination work, national authorities are constrained in transposing EU legislation into the national context.

Second, EU level agents often perceive their possibilities to influence national scale institutions to be rather limited. Based on past experiences, interviewees state that they expect to encounter

[25] The Scholz government with its so called 'traffic light' coalition between Social Democrats (SPD), Greens (Bündnis 90 / Grüne) and Liberal Democrats (FDP) began government work in December 2021. Accordingly, the leadership of the Ministry for Economic Affairs and Climate Action (BMWK) changed with the Greens succeeding the Union parties CDU/CSU.

reservations, being accused of imposition or not being taken seriously by, for instance, national ministries. The latter is reinforced by an often lacking consciousness about EU decision-making power at the national level. In this regard, national level interviewees highlight further factors diminishing its credibility at a national scale; first, the leeway for national governments to implement EU legislation and, second, the Commission often occupying much time for overseeing the implementation of EU-legislation and imposing infringement procedures, especially regarding a niche market such as residential storages.

Third, also regarding the EU level, our empirical material suggests that institutional semi-coherence due to spatial variation in member states (Fünfschilling & Binz 2018) constrains rescaling activities at EU scale. As mentioned above, member states' positions vary a lot based on, for instance, differences in energy mixes. These differences are reflected in member states' regulation, which results in abstract EU targets and policies, especially regarding niches such as residential storages. Furthermore, as mentioned above, agents embedded at EU level, such as industry associations, who pool different national associations or companies, focus on rather abstract targets instead of fostering specific business models involving residential storages. In this context, the associations further emphasise technology neutrality, the diversity of technologies and the high number of market segments covered.

However, there are also encouraging conditions for engaging in rescaling activities. Especially national agents consider institutional work activities at EU scale increasingly influential (unless they are constrained by a lack of monetary and personal resources). First, even though contradicting to statements by EU level agents, many national interviewees expect a positive narrative around the need and potential of residential storages prevailing at EU level, which eventually helps to induce regulatory changes, also at a national level.

Second, some actors regard the legislative procedures at EU scale as being more transparent compared to Germany. This is reinforced by, for instance, publicly accessible amendment proposals, by the possibility to take part in committee meetings via videoconferencing or by transparency registers, which document lobbying activities reaching the Parliament and Commission.

Third, standardisation (e.g., communication interfaces for connecting different devices in private energy management systems) is considered an issue to be treated at a supranational scale in order to expand the market.

Fourth, with respect to the EU level, sharing nationalities is stated to help to legitimise and get access to members of Parliament (MEPs) and the Council. In this context, some interviewees see their potential influence backed by the size of Germany as member state.

Lastly, being embedded at both scales widens actors' possibilities to influence institutions. As mentioned above, lacking knowledge about EU legislative processes constrains national agents (particularly smaller organisations or companies) in engaging at an EU level, while highly complex national regulation constitutes a barrier for EU level actors. Thus, multi-scalarly organised associations or electricity providers maintaining offices in Brussels are attributed high agency, as they are facilitated to monitor national and EU level legislation (enabling educating), have access to decision-making at both levels as well as enjoy legitimacy at both scales.

6.5 Discussion

6.5.1 Institutional rescaling work

Our case reveals that especially national actors traditionally engaged at a national scale in shaping regulation and discourses increasingly carry out activities at the EU scale. As regards agents endowed with strong agency, our findings emphasise established, legitimised players like electricity utilities or industry associations consolidating, for instance, electricity utilities, storage manufacturers, DSOs or automobile companies. This might be reinforced by the sectoral environment of electricity generation and the German context, which is characterised by high advocacy activities of powerful incumbents and industry associations (Meckling & Nahm 2018). Our results show that these actors, which enjoy a longstanding access to political institutions at a national scale (blinded reference[26]), are at the same time the actors most successful in getting access to institutions at other scales.

Regarding influential institutional work activities, our case emphasises a high relevance of political advocacy. The specific sectoral context of electricity generation reinforces the importance of addressing regulative institutions by means of classic political advocacy, as the diffusion and feasibility of business models is strongly linked to national and EU level regulation (Duygan et al. 2021a). Furthermore, national agents aim at changing the prevailing associations at an EU scale by presenting residential storages as possible solution to grid problems resulting from the increasing integration of renewables (Finstad and Andersen 2023). The relevance of narratives might be reinforced by the transparency of consultation processes around legal amendments and the strong normative dimension of renewables and e-mobility. The specific multi-scalar arrangement is reflected by the importance of policing[27], in other words, setting standards concerning, for instance, metering and communication. Especially private companies engage in policing[25] at a supranational scale in order to expand their market.

6.5.2 Scalar conditions impeding and triggering rescaling

This paper takes account of scalar conditions shaping actors' purposes and possibilities to engage in rescaling, which proposes a link between agency and structure (Tab. 10). Most importantly, we found institutional semi-coherence, holding positions at multiple scales as well as experiences and perceived expectations as scalar structures conditioning agency.

First, our results unveil that institutional semi-coherence constrains socio-institutional rescaling, which is a rather counterintuitive finding. In transitions literature, institutional semi-coherence is considered to trigger transitions, since the mimetic pressure evoked by the dominant regime is restricted and less institutional work is needed to institutionalise alternatives challenging a regime. Furthermore, inherent conflicts and contradictions broaden the scope of legitimate agency and, thus, legitimise institutional work (Miörner & Binz 2021; Fünfschilling & Binz 2018; Fünfschilling & Truffer 2014). In our case, however, institutional semi-coherence at EU level complicates socio-institutional rescaling. First, favourable institutions (e.g., policy targets, legislation) remain abstract, as they should be implementable in all member states, which are characterised by high spatial variation. Second, institutional work activities of agents embedded in institutional semi-coherence (e.g., EU level industry associations) lack common

[26] This reference refers to Käsbohrer et al. (2024).
[27] As mentioned in chapter 6.4.2, *defining* is meant here instead of *policing*.

objectives and, instead, are directed at higher-level targets fitting the different preconditions. This withholds national actors from collaborating with EU-level agents.

Second, holding positions at multiple scales, such as associations' branch offices and corporate representations, facilitates actors' engagement in rescaling. This corresponds to Grillitsch (2015), who reveals that agents, being subject to two or more institutional layers, are able to mediate interests, translate behaviour and facilitate knowledge transfer between layers. Thereby, trust-based networks and knowledge exchange are fostered by institutional proximity (Grillitsch 2019; 2015). Speaking of regional development paths, Grillitsch and Sotarauta (2020) argue that individual networks and moving between positions in different respects, ranging from profession, education, sector, social embedding or location, shapes individual experiences and encourages actors to recognise opportunities for change. Conceptualising enabling conditions for institutional work, Duygan et al. (2021b) argue that the relevance of networks results from the opportunity of binding actors that are otherwise not linked. Our results confirm the relevance of networks given a multi-scalar arrangement. Agents embedded at both scales (companies or multi-scalarly organised associations) are associated with high agency due to easier access to decision-making, to knowledge (e.g., on regulation at both scales) and knowledge exchange, as well as legitimacy in the sense of being accepted for establishing networks also across scales. Furthermore, these agents act more independently of mind barriers such as expected reservations or the perception of not being taken seriously by, for instance, national ministries.

Third, these mind barriers are one example of experiences and perceived expectations that we found to be scalar structures conditioning agency. Agents embedded at the EU scale do not expect to have a high impact at the national level due to the 'convention' of keeping the layers separate, which also stems from facing reservations in the past. By contrast, anticipated positive narratives as well as transparency of EU decision-making and the perceived relevance of standardisation at a broader spatial scale encourages national agents to engage in institutional work. These results correspond to Grillitsch et al. (2024), who highlight the relevance of perceived opportunities for agency in the context of regional development paths, especially regarding opportunities outside the dominant development narrative.

Table 10: Overview of scalar conditions impeding and enabling rescaling.

Conditions impeding rescaling	Conditions enabling rescaling
Institutional semi-coherence	Holding positions at multiple scales
Lacking knowledge on regulation	Expected positive narratives
Complex regulation at both scales	Expected transparency
Expected reservations	Perceived relevance of standardisation
Underestimated EU impact at a national scale	German market size
Lack of monetary or personal resources	National perspective

Source: Author's elaboration.

6.5.3 A relational perspective on scales

Particularly political economists take on a relational perspective on scale stressing mutual formative interactions when actors establish, differentiate, hierarchise and reorganise spatial units (Brenner 2001; Howitt 1993). In this context, rescaling fits well by focusing on the reconfiguration of scalar boundaries (Grillitsch et al. 2025). However, instead of formal changes, for instance, a shift in formal decision-making power (Madsen 2022a our case represents an example of spatial scales, which are restructured in terms of their *"relative importance"* (Swyngedouw 1997, 141). On the one side, we observe institutional work activities strengthening the role of the European scale in the national context in the form of a rapid and thorough implementation of EU legislation. On the other side, especially national actors aim at fostering the originally German configuration of residential storage systems along with the associated narratives and regulation at the EU level.

Consequently, we observe mutually formative interactions, since the path development of the market for residential storage systems in Germany cannot be traced without taking account of the causal power played out at the EU scale. Our study shows how actors deliberately make use of institutional properties at this supranational level, when seeking to strengthen or even spatially expand an industrial development path to other countries, i.e. rescaling institutions vertically to other countries by using the European level as leverage. At the same time, the rescaling of national institutional rationales influences the European scale, for instance, by leading to institutional semi-coherence due to spatial variation. This corresponds to Brenner (2001, 606) arguing that "*[e]ach geographical scale is constituted through its historically evolving positionality within a larger relational grid of vertically 'stretched' and horizontally 'dispersed' sociospatial processes, relations and interdependencies".*

6.6 Conclusion

This study focuses on the agentic dimension of rescaling. More concretely, we shed light on why, how and with what outcomes actors engage in socio-institutional rescaling through institutional work activities in order to foster the diffusion of residential storage system in Germany and at a European level. Furthermore, we take account of actors' purposes and possibilities based on the scalar arrangement they are embedded in.

In light of regulatory barriers for advancing business models, particularly national industry associations and companies aim at socio-institutional rescaling by advocating a thorough implementation of EU legislation benefitting this renewable energy niche in Germany, and scale it to other countries. The future-oriented dimension of agency manifests itself in institutional work at a European scale, in spreading the narrative around residential storages, influencing legislative amendments and setting standards regarding metering and communication. By contrast, agents embedded at a European scale, for example, industry associations or NGOs, are constrained by scalar structures, such as institutional semi-coherence due to pooling national differences in regulations and targets or the expectation of reservations at a national scale. Thus, being embedded at both scales, for instance, by means of corporate representations, is associated with high agency due to expertise on the legal environment, access to decision-making as well as legitimacy at both scales.

A limitation of this case study lies in establishing causality between institutional work and institutional change, with, for instance, a newly introduced government or the delayed introduction of smart meters rivalling institutional work activities. Furthermore, there is a strong focus on regulation and advocacy work, since business models involving residential storages are mainly hampered by regulatory barriers. Thus, we suggest further studies with a less pronounced role of regulation. Furthermore, case studies focusing on other institutional architectures (on a local or global scale) merit further attention, as advocacy work might be further overemphasised given the EU specific multi-level governance processes. In conceptual terms, future research potential lies in investigating whether and how institutional work activities aiming at socio-institutional rescaling at the same time trigger spatio-temporal and techno-economic rescaling.

7 **Article III:** Regulatory state capacity for accelerating net-zero transitions: Lessons learned from governing electricity storage in Germany[28]

Abstract: Policy implications arising from the unique challenges in the acceleration phase of net-zero transitions are receiving increasing attention. As a refinement, this paper focusses on regulation as a subset of policies and investigates the regulatory implications of such acceleration challenges. We integrate the literature on transformative policy capacity for conceptualising regulatory state capacity needed for responding to these challenges through regulatory change. This regulatory state capacity is operationalised by means of roles, abilities and resources. We apply our analytical framework to the market for electricity storage systems in Germany. Based on in-depth interviews and participant observation we find a high institutionalisation and complexity of regulation, and an accelerating effect of multi-system interactions on and contestation around regulatory changes. Our research reveals that in Germany regulatory state capacity has been characterised by a high relevance of gatekeeping and moderating as well as political abilities in light of the challenges 'whole system change' and 'expansion and contestation'. We further observe a change in roles, from a maintaining to a creating character, and different sources of more radical regulatory change: while the changing attitude towards residential storage in the regulatory agency is based on learning and reflexivity due to its role as observer, warner and mitigator embedded in a changing socio-technical environment, the changing regulatory state capacity in the investigated ministry is triggered by the change of government and the associated stronger political will from inside the organisation itself. In conclusion, the article provides recommendations for policy makers with a focus on regulation.

7.1 Introduction

The bulk of established research on energy transitions has largely focused on niche innovations, which challenge established regimes and emerge in tandem with closely associated developments such as the entry of new players or changes in businesses models, value chains, policies, and user practices (Araújo, 2023; Köhler et al., 2019). However, as such transitions progress, some technologies are moving to the next transition stage, when socio-cultural, economic, ecological and institutional changes accumulate and interact (Rotmans et al., 2001). In transition studies, this later stage is often referred to as acceleration phase of transitions, when niche innovations enter mainstream markets, widen their scope in geographical diffusion and advance into adjacent systems (Sovacool et al., 2025; Markard et al., 2020; Roberts et al., 2018). These developments trigger a redefinition of existing institutions along with significant contestation and resistance (Lindberg and Kammermann, 2021; Kivimaa et al., 2019; Roberts and Geels, 2019; Schot and Kanger, 2018).

[28] The article was published in the Journal *Energy Policy* in May 2025. This journal offers a platform for reporting studies on the policy implications of energy supply and use focusing on their economic, social, planning and environmental aspects (Elsevier 2025b). Thus, this text is the published version. The article has been co-authored by Karoline Rogge, University of Sussex Business School, UK, and Fraunhofer Institute for Systems and Innovation Research (ISI), Germany, and Hans-Martin Zademach, Catholic University of Eichstätt-Ingolstadt, Germany. I was the lead and corresponding author for this paper. The co-authors made valuable contributions in conceptualising the paper.

Recent contributions have categorised challenges unique to this aceleration phase, namely 'whole systems change', 'interaction between multiple systems', 'decline and resistance', 'expansion and contestation', 'consumers and social practices', 'justice', 'international dynamics' and 'governance' (Sovacool et al., 2025; Rogge and Goedeking, 2024; Markard et al., 2020). These challenges might prevent the acceleration of transitions and require substantial efforts from multiple actors to address them, including from policy makers. However, the resulting policy implications remain vague and do not consider required capacities of policy makers to tackle such challenges, in particular regarding changing regulation. We close this gap in the literature by shedding light on the regulatory implications of the novel challenges in the acceleration phase of transitions, thus, contributing to a long-standing but somewhat side-lined debate on the role of regulation in transforming socio-technical systems (Blind, 2024; Raven et al., 2016; Smith and Raven, 2012; Geels, 2004).

Conceptually, we draw on the emerging literature on the role of governments, governing entities and civil servants in transformative change, along with their constraints and capacities (Borrás et al., 2024; Song et al., 2023; Borrás and Edler, 2020). In particular, we focus on state capacity required for regulatory change that addresses challenges arising in the acceleration phase of net-zero transitions, instead of maintaining the status-quo. Building on work of Borrás et al. (2024) and Wu et al. (2015), we introduce the term "regulatory state capacity", which we define as the roles, abilities and resources necessary to design and adopt regulatory changes required to tackle acceleration challenges

Empirically, we provide new original insights from a particularly telling case, namely the market for residential storage systems in Germany with its energy transition being in the midst of the acceleration phase. As will be shown, residential storages present a suitable case for analysing acceleration challenges and required regulatory state capacities, since regulatory barriers challenge the further development and upscaling of more comprehensive business models including, for instance, grid services. Hence, we raise the following research question: *How do Germany's governing entities tackle the regulatory implications resulting from the acceleration challenges associated with the growing market for residential storage systems?*

The remainder of the paper is structured as follows. The next section presents the conceptual background of our study and outlines our analytical framework. After introducing our research design and case (section 7.3), we identify acceleration challenges and their regulatory implications in the market for residential storage systems in Germany (section 7.4). We show how governing entities respond to these challenges by analysing their roles, resources and abilities. In section 7.5, we discuss overarching regulatory implications, the features standing out for a high regulatory capacity and offer recommendations for policymaking. Section 7.6 concludes by discussing limitations of this study and future research lines.

7.2 Towards an analytical framework for investigating regulatory state capacity for accelerating net-zero transitions

In this section, we first introduce our key concepts, namely acceleration challenges, policies in general and regulation in particular, and capacities of governing entities. Drawing on these key concepts, we then outline our research framework applied to analyse the regulatory state capacity for accelerating net-zero transitions

7.2.1 The role of policy in accelerating net-zero transitions

Transition scholars have identified several challenges associated with the acceleration phase of sustainability transitions. Markard et al. (2020) identified the following 'acceleration challenges' relating to the focal and adjacent systems: whole system change, interactions between multiple systems, resistance from declining industries, changes in consumer practices and routines, and coordination challenges in policy and governance. Drawing on the case of transport electrification in Germany and California, Rogge and Goedeking (2024) complemented these challenges by introducing three additional ones: expansion and contestation, international dynamics, and justice.

Both Markard et al. (2020) and Rogge and Goedeking (2024) identify policy makers as essential for accelerating transitions and derive relevant implications for policymaking (for details see Table 11). According to Markard et al. (2020), policymaking, first, needs to be more integral inducing changes in entire systems across domains instead of fostering single innovations. Second, a broad range of actors should engage in policymaking for nurturing social acceptance or forging supportive industry coalitions. Third, a stepwise applied, broad mix of policies (standards, incentives, subsidies, taxes) is required. Finally, particularities of different sectors and places need to be acknowledged. In addition, Rogge and Goedeking (2024) emphasise the need for responding to contestations in adjusting institutional frameworks, applying a broad justice approach as well as considering transnational policy feedbacks.

Table 11: Overview of different challenge types in the acceleration phase and their policy implications.

Acceleration challenge	**Description**	**Policy implications**
(1) whole system change (WHO)	Major changes in system: complementary interactions between multiple innovations, fundamental changes in system architecture	Focus on entire systems instead of singular innovations, support experimentation with socio-technical system change instead of sole focus on technological change
(2) multi-system interactions (MSI)	Increasing changes in the interaction of multiple systems, with a focus on tensions in multi-system interactions	Overarching, cross-cutting missions; non-compartmentalised, more integral policy making; multi-system task forces
(3) decline and resistance (DEC)	Decline of existing industries and businesses, and multi-actor resistance to such decline	Support structural change and reskilling of work force, create social acceptance, forge winning coalitions, compensate losers
(4) expansion and contestation (EXP)	Contestation around the expanding trajectory, incl. framework conditions for new mass markets, securing future market shares and gains	Update electricity market designs, regulate data access, set product and green finance standards, incentivise faster portfolio shifts to clean tech
(5) changes in consumer practices and routines (CON)	Major changes in consumer practices and demand patterns	Stimulate technology adoption, behavioural change and learning-by-using processes; enable new business models; adjust planning

Acceleration challenge	Description	Policy implications
(6) justice (JUS)	Multi-dimensional justice implications of system changes and affordability of new technologies for low-income households	Include a broad justice approach in policy design and evaluation, tailor policies to low-income households
(7) international dynamics (INT)	Global interplay driven by international competition, pioneering countries, geopolitical risks, changes in global value chains	Renewed focus on green industrial policy, strategic resource partnerships, free trade clubs among like-minded partners
(8) governance (GOV)	Increasing complexity of governance, policy paradigm change towards greater policy intervention	Stronger vertical and horizontal policy coordination, governance reform, designing policy mixes for creative destruction, policy sequencing

Source: Rogge and Goedeking (2024), building upon and extending Markard et al. (2020).

However, so far the discussed policy implications remain at a very high level of abstraction, with little insights on the specific role of regulation in the acceleration phase of transitions. Indeed, more generally speaking, research on the role of regulation for sustainability transitions has been limited, but started to be emphasised (Geels and Gregory, 2023). Such considerations should build on the seminal literature on the Porter hypothesis (Porter and van der Linde, 1995a, b), which suggests that strict environmental regulation triggers 'innovation offsets' resulting in resource productivity and higher economic efficiency. Notwithstanding, the literature has remained ambiguous in the understanding of regulation, with two main literature streams to be distinguished (Fig. 12).

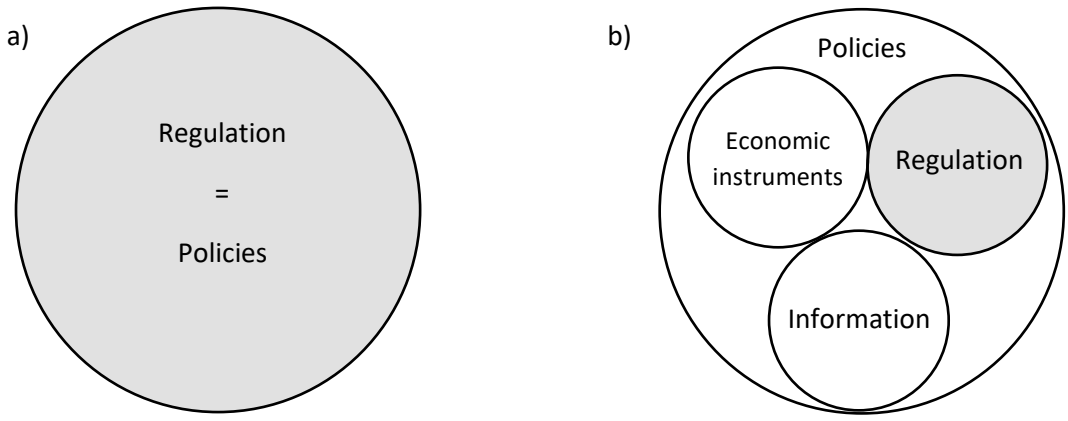


Figure 12: a) Regulation in the broader sense and b) regulation in the narrower sense
Source: own elaboration.

The first stream of research considers regulation nearly as a synonym for policies, which we refer to as *regulation in the broader sense*. According to Braunerhjelm et al. (2023), a common thread among such definitions on regulation refers to political authority enforcing compliance to regulations, as shown by the OECD (2023, 10): *"Regulation is the diverse set of instruments by which governments set requirements on enterprises and citizens. Regulation includes all laws, formal and informal orders, subordinate rules, administrative formalities and rules issued*

by non-governmental or self-regulatory bodies to whom governments have delegated regulatory powers." A wide range of tools is considered as regulation, ranging from 'command and control' measures to instruments influencing the incentives and, thus, the behaviour of economic agents. Examples are (quality) standards, price controls, taxes and demand subsidies, disclosure of information or ownership ceilings (Braunerhjelm et al., 2023; OECD, 2023). Only few regulations have the immediate objective of promoting innovation, for example, by ensuring intellectual property rights. Instead, most regulation aims at correcting market failures, optimising social welfare, containing externalities, and reducing transaction costs (Braunerhjelm et al., 2023; Blind, 2023). Indirect pressure to innovate might be created by the need to comply with, for instance, more rigorous environmental requirements (Blind and Münch, 2024; Braunerhjelm et al., 2023).

The second stream of research regards regulation as one type of several policy instruments, i.e. *regulation in the narrower sense* (e.g., Edler et al., 2016; Rogge and Reichardt, 2016; Reichardt and Rogge, 2013; Rennings and Rammer, 2011; IEA, 2024; IRENA, 2012; UNFCCC, 2000). Broadly speaking, this stream contrasts regulation as command and control measures with economic, i.e. market-based, instruments as well as information (Reichardt and Rogge, 2013). Economic instruments encompass, for instance, tax incentives, grants and loans, subsidies or trading systems. Policies targeting information include professional training on new technologies or public information campaigns. By contrast, regulation understood in the narrower sense focuses upon intellectual property rights, technology/performance standards or market designs such as grid access guarantees or priority feed-ins, to name a few examples. The underlying logic can be traced back to research in environmental economics, which refers to the regulatory strategy of "command-and-control" (Baldwin et al., 2012; Baldwin, 1997). Thus, regulation has been specified as *"the direct regulation of an industry or activity by legislation that states what is permitted and what is illegal"* (McManus, 2020). Command-and-control refers to the standards set by the state, which can be imposed by force of law. In addition to standards controlling the quality of services and products or the manner of production, command-and-control regulation can also govern the allocation of products or commodities and the prices charged to consumers (Baldwin et al., 2012). As the electricity market design is a telling example for a command-and-control regulation, we build on this latter stream, i.e. in this paper we understand regulation in the narrower sense.

The few emerging studies that have paid dedicated attention to the role of regulation in transitions have tended to build upon the conceptual approach of regulation in a broader sense. For instance, Blind (2024) uses the OECD definition for examining the role of regulation related to the policy intervention points for sustainability transitions according to Kanger et al. (2020), effectively including any policies, not just regulation. In the context of experimentation, Bauknecht and Kubezcko (2024, 45) analyse the impact of regulatory experiments and real-world labs on the directionality and acceleration of transition processes, including *"not only regulation in a narrow sense, but rather the full range of public policy instruments."* Other transition studies do not clarify their definition of regulation, leaving their interpretation ambigious. For example, studying the bioeconomy in Germany and the mobility transition in the Netherlands, Edler et al. (2021) consider regulation as contextual system component, but summarise "policy and regulation" as one transformation dimension. Similarly, Feser et al. (2024) conduct a comparative study on the up-take of 27 international regulatory experiments for sustainability transitions, yet do not focus on the regulatory content itself but on the experiments' transferability, scalability, and unintended consequences.

Taken together, we see a lack of conceptual clarity in studies on regulation with one stream of literature referring to regulation as synonymous with policies (regulation in the broader sense) and another stream considering regulation as one sub-set of policy instruments (regulation in the narrower sense). We argue that it is important to differentiate both streams, and that future research needs to advance both our understanding of policy in general for accelerating transitions, but also and even more so of regulation in particular. Therefore, we suggest to use policy as overarching term, whereas studies focusing on regulation – in the narrower sense – should unpack the specific instrument type and its relative role in accelerating transitions (see Fig. 12 b). In doing so, we agree with Blind (2024, 11), who calls for more regulation-related research on the *"agency of the involved actors […] driven by their interests and enabled by their means"*. In this vein, we now elaborate on our conceptual consideration for analysing the regulatory capacity of state actors for inducing regulatory changes in accelerating net-zero transitions.

7.2.2 Capacities and capabilities for governing transitions

There is a wide scholarship on the governance of transitions (Köhler et al., 2019; Frantzeskaki et al., 2012), with transition scholars increasingly acknowledging the relevance of the state for governing sustainability transitions (Johnstone and Newell, 2018). Recent contributions particularly concern the organisational level of state actors, using different terms and emphases, e.g., regarding roles and tasks (for an overview, see Appendix N). For example, Borrás and Edler (2020) identify various embedded roles of the '*state'* depending on distinct modes of governance in socio-technical systems. Relatedly, Braams et al. (2021) compare the transition tasks of '*governments'* with the normative arguments of the Public Administration traditions for legitimising government action. Braams et al. (2022, 2023) focus on *'civil servants'* in the Dutch ministry for infrastructure and water, analysing their perception on their legitimacy and tactics for realising transition tasks. In addition, Borrás et al. (2024) propose a conceptual framework capturing the 'transformative capacity' of '*public sector organisations'* for changing institutions consisting of roles, resources, and abilities. While studying the dynamic interactions of Chinese 'governing entities' in designing the policy mix for electric vehicles, Song et al. (2023, 3) refer to entities *'in charge of the design, implementation, and governance of the focal policy mix'*. For our purposes of investigating regulating and legislating entities relevant for regulatory change, we consider 'governing entities' as most appropriate term – it is not too broad such as 'the state' or any 'public sector organisations' nor too narrow such as 'civil servants'.

As regards the capacity of state actors, the literature on sustainability transitions focuses on various dimensions and scales, often on a systemic (national) level (e.g., La Belle, 2017; Konrad et al., 2021) or an urban scale (e.g., Wolfram, 2016; Hölscher, 2020). Concerning the organisational level, some contributions focus on *'green dynamic capabilities'*, particularly of governmental organisations for creating and implementing green innovations (Arshad et al., 2023; Van Welie et al., 2019). With respect to the acceleration phase, Rogge and Song (2025) investigate transformative policy capacities for accelerating transitions by taking acceleration challenges and policy mix intervention points into consideration. Based on a review of the literature on public governance and public administration studies, innovation studies and sustainability transitions, Borrás et al. (2024) conceptualise the transformative capacity of public sector organisations as interaction of the three core constitutive elements roles, resources and abilities. We adopt this arrangement of roles, resources and abilities, since we consider the interaction of these three elements valuable for analysing the capacity of governing entities needed in the acceleration phase.

As first element, roles of state actors mean the variety of purposeful tasks when enacting institutional work during transitions. Acknowledging the purposeful character of these roles, Borrás et al. (2024) follow the guidance provided by the literature on institutional work and, thus, distinguish roles, which aim at creating, maintaining and disrupting institutions towards system change (Lawrence and Suddaby, 2006).

Resources are defined by Borrás et al. (2024) as the set of internal or external material or immaterial assets that that can be mobilised by state actors to enact their transformative roles. They differentiate between human, physical, financial, legitimacy, network and cultural resources, as well as political mandates and data and information. By human resources, for instance, they mean staff and man power. Legitimacy resources relate to reputation, social acceptance and authority as well as trustworthiness. Political mandates mean the legal and regulatory status. By means of network resources, they refer to contacts, access to decision making, relational and inter-organisational resources. Cutural resources encompass public administration and bureaucratic culture or the general organisational culture in the society.

Table 12: Abilities for transformative capacity in the acceleration phase.

Type of abilities	Explanation
Analytical abilities	Exploring, studying, and interpreting and, more concretely, mobilising original and relevant new knowledge, to advice for public action, to develop new ideas and visions, also including new forms of public innovation, futuring and anticipatory skills in various forms, future-scenario building, simulation models, or similar anticipatory tools as well as the ability to develop imaginaries in relation to socio-technical transformations.
Operational abilities	Managerial and administrative abilities to put in place the practical operation needed for transformative action, such as, securing legal enforcement, administrative or managerial skills as well as effective reporting, monitoring, verification, and sanction mechanisms.
Coordination abilities	Ability to develop and engage in inter-organisational collaboration with other public organisations across government levels, and to participate in governance networks or social innovation networks.
Learning and reflexivity abilities	Ability to develop and incorporate new understandings and adjust its own action accordingly, by means of adaptation and re-consideration.
Political abilities	Dealing with political judgements, cross-actor negotiations or trade-offs and the establishment of new governance structures encompassing, for instance, communication with stakeholders and the general public, stimulating and orchestrating multi-stakeholder participation, communication and engagement, negotiations and consensus building.

Source: Own compilation based on Borras et al. (2024) and Wu et al. (2015).

Abilities are the routines, practices, and procedures inside the organisation when exercising transformative agency (Table 12). Borrás et al. (2024) cluster these abilities into four categories: analytical, operational, coordination, as well as learning and reflection. We complement this by political capacities, for which we draw on Wu et al. (2015). Therewith, we respond to Rogge and Song (2025), who call for more research on organisations' political capacities for accelerating transitions, since governing entities will be key in navigating the 'dual politics' of transitions (Rogge and Goedeking, 2024): overcoming political pressures from powerful, established regime actors and reaching political trade-offs between different groups of actors, especially

across different socio-technical systems, for building the new regime (see also Avelino and Wittmayer, 2016; Stirling, 2014). Thus, we further take account of context-specific conditions (Roberts and Geels, 2019; Roberts et al., 2018), as we expect political skills to be critical in the German context. For this, recent contributions emphasise political contestation and the resistance of automotive incumbency related to transport electrification policy (Meckling and Nahm, 2018; Rogge and Goedeking, 2024) and regulation (Käsbohrer et al., 2024).

7.2.3 Analytical framework for investigating the interplay between regulation and acceleration transitions

To address the identified shortcomings in both literature streams, we develop an interdisciplinary analytical framework that bridges the gap between the literatures on acceleration challenges and on state capacities for governing transitions, with a dedicated focus on regulation as one type of policies. Our framework consists of the following two major building blocks: first, acceleration challenges with their regulatory implications, and second, regulatory state capacity enabling regulatory change needed to tackle these acceleration challenges, thereby paving the way for speeding up net-zero transitions. More specifically, and as schematically displayed in Fig. 13, we thus identify regulatory implications, which result from challenges unique to the acceleration phase of transitions (left part of our framework). Here, we focus on regulation in the narrow sense, thereby emphasising the specific relevance of regulation in the acceleration phase (see section 7.2.1). Simultaneously, we detect what kind of state capacity is necessary for responding to these challenges through regulatory change, thereby aiming for accelerating transitions (right part of our framework). As outlined in section 7.2.2, this regulatory state capacity is operationalised by means of roles, abilities and resources.

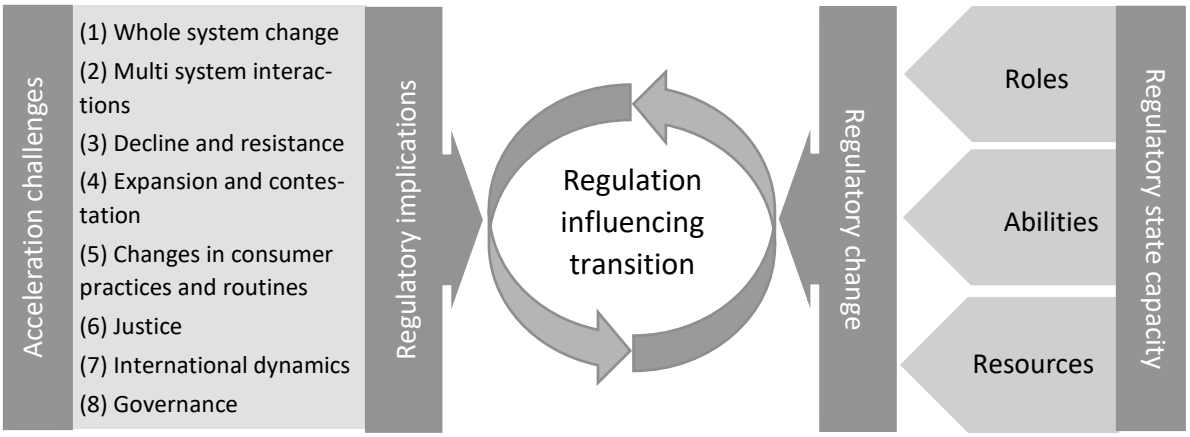


Figure 13: Analytical framework for investigating the role of regulation in accelerating transitions. Source: own elaboration.

7.3 Research design

In order to gather in-depth insights on the agency of governing entities on an organisational level, we conduct a qualitative case study (Yin, 2014). In the following, we first provide an overview of the selected case, before describing data collection and analysis.

7.3.1 Case selection

Our research case covers electricity storage in general, and residential storage in particular. In this regard, the initially most common use case of residential storage systems (up to 30 kWh) was "prosuming" (a terminological hybrid of producer and consumer), which aims at enhancing self-production and self-consumption of solar electricity in private households by storing surplus electricity beyond current consumption (Fig. 14; Tepe et al., 2021; Kairies et al., 2019). Since then, further business models have been developed. Residential storage is part of private energy management systems (smart homes), which facilitate demand side flexibility by connecting electrical loads (storages, heat pumps, electric vehicles, etc.) and producers (typically photovoltaics). These behind-the-meter systems (which means that electricity is used without passing through a meter) have been complemented by more system-relevant front-of-the-meter applications providing electricity to locations beyond the private home, for example, feeding the grid. More specifically, large numbers of digitally aggregated photovoltaic and storage systems (so-called virtual power plants) can provide a frequency containment reserve in order to balance variation of mains voltage through storing or withdrawing electricity during times of interruption or overproduction (Becker et al., 2024; Sousa et al., 2019). Moreover, such virtual power plants can take advantage of price volatility in international electricity trade through timed sales. Another potential use case are so-called "energy communities" organised by a third party aggregator (so-called energy sharing), enabling members to sell and buy electricity from other peers depending on their current demand or surplus production (Blasch et al., 2021; Mlinaric et al., 2019).

Against the backdrop of these developments, several aspects substantiate our case: First, given the necessity of storing electricity generated with renewables, the technology by itself constitutes a necessary complementary interaction for whole system change, which becomes crucial to tackle in the acceleration phase of net-zero transitions (Markard et al., 2020; Markard and Hoffmann, 2016). Moreover, residential storage systems contribute to a changing system architecture by facilitating decentral self-generation and self-consumption in private households (Wieczorek et al., 2024; Andersen et al., 2023b). Not least, we observe an increasing integration with other systems, such as mobility and heating, with such multi-system interactions being another characteristic for accelerating net-zero transitions (Andersen et al., 2023a; Löhr and Chlebna, 2023; Mäkitie et al., 2022; Rosenbloom, 2019).

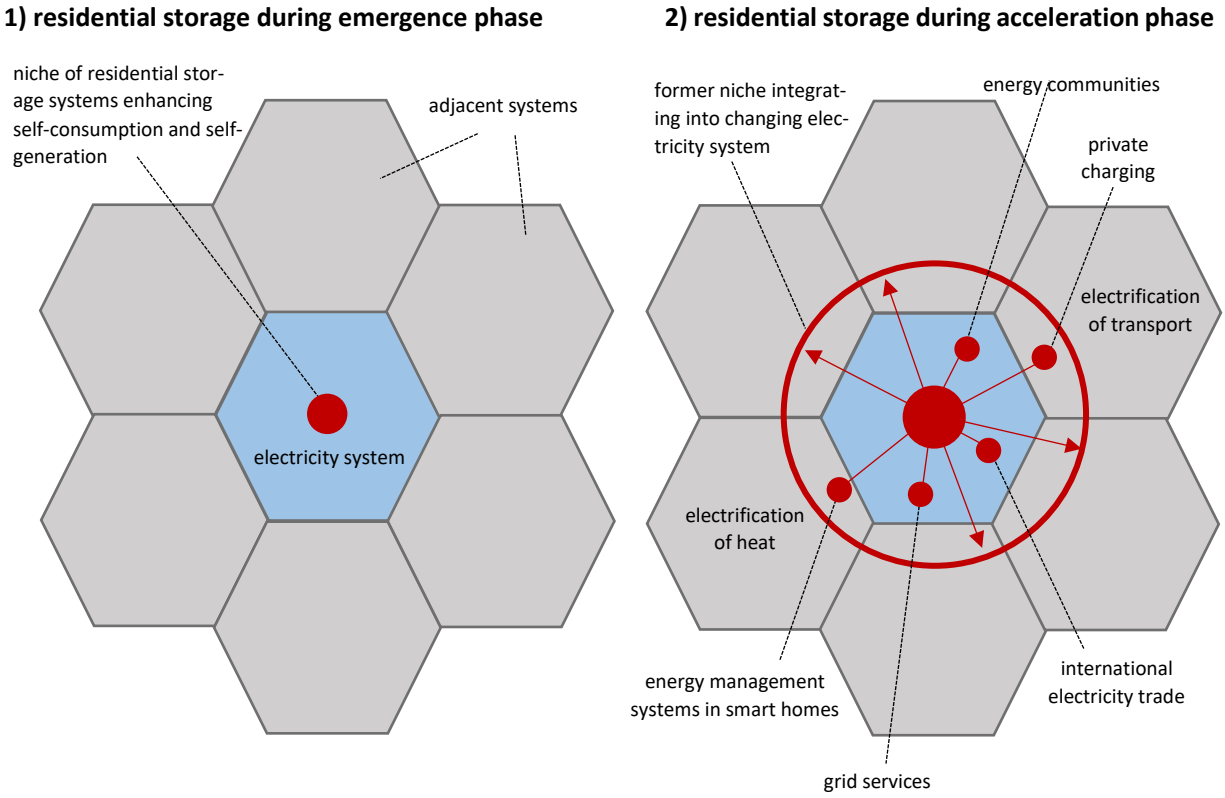


Figure 14: Positioning the residential storage system in the transitioning electricity system: 1) during emergence phase, 2) during the acceleration phase.

Source: Own elaboration based on Markard et al. (2020)

We argue that Germany constitutes a telling example for investigating the regulatory implications arising from the challenges occurring in the acceleration phase of net-zero energy transitions and the regulatory state capacities for regulatory change. First, Germany has advanced significantly in its transition away from fossil fuels and nuclear energy towards renewables, as evidenced by a rapid expansion of installed PV capacity. This is connected to high dynamics in the market for residential storages systems as well as e-mobility (Fig. 15). Second, the market for residential storage systems in Germany was the largest in Europe in absolute terms as well as relative to population in 2022 (ees Europe, 2023). This market for residential storage systems dates back to the first decade of the new millennium, with a significant take-off in the years 2013 and 2014. Finally, advocates of residential storage systems (e.g., industry associations, storage manufacturers and electricity providers) regard regulation in Germany as key obstacle to a more profitable realisation of business models involving storage systems beyond self-consumption due to, for instance, fees and charges or complex metering requirements (Käsbohrer et al., 2024; Zademach and Käsbohrer, 2022). Thus, the German case is very suitable for analysing the required alignment of regulation in response to the challenges arising in the accelerating phase of net-zero transitions.

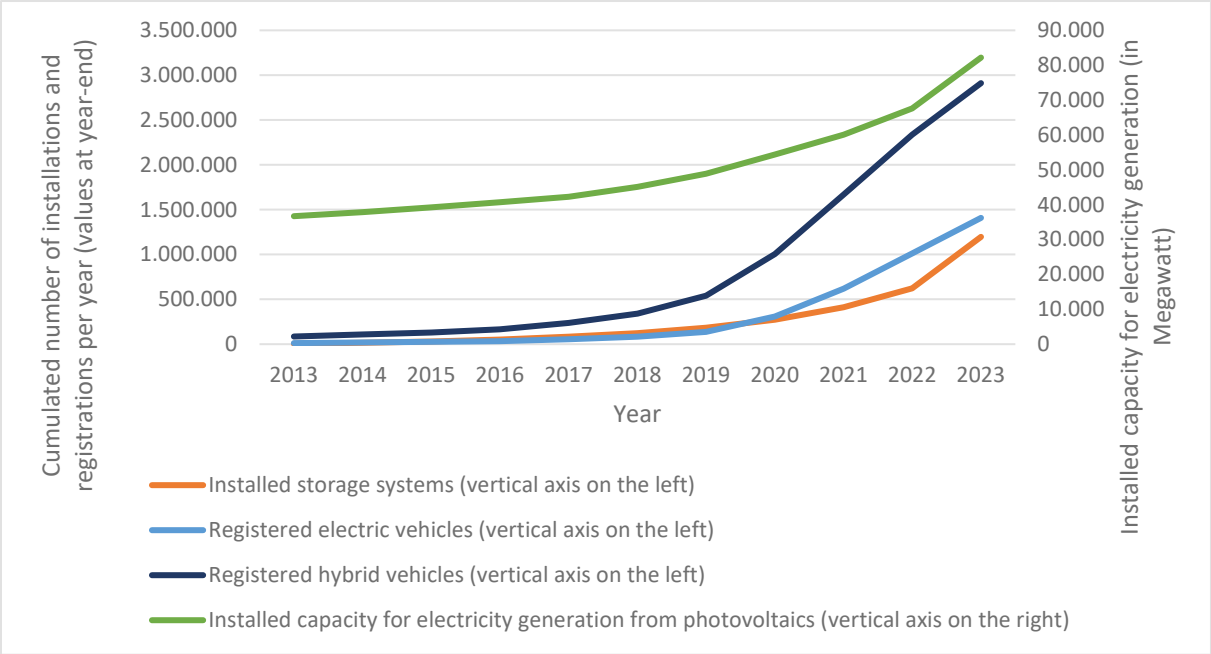


Figure 15: Installed capacity for electricy generation from photovoltaics (in Megawatt), cumulated installation figures of stationary residential storage systems (up to 30 kWh) and stock of licensed passenger cars with electric or hybrid engines for the years 2013 until 2021 in Germany, estimated and rounded values at year-end.
Source: Own illustration based on Bundesverband Solarwirtschaft e.V. (2024); Kraftfahrt-Bundesamt (2024, 2023b); Umweltbundesamt (2024).

7.3.2 Data collection and analysis

Empirically, we conduct a case study on residential storages, drawing on two data sources: expert interviews and participant observation. Our qualitative analysis is primarily based on the insights gained through our semi-structured expert interviews (covering business, governing entities, research etc.) conducted in two phases between February 2021 and September 2024 and yielding a total of 39 interviews with close to 2400 min of interview material (see Table 13). This interview data was enriched by participant observation in industry association meetings, which included 45-min to day-long events and provided valuable context information on regulatory amendments and industry stakeholders' reactions (See Appendix O).[29]

The scoping phase (between September 2020 and April 2023, 31 interviews) allowed us to understand the technology and associated business models as well as to identify relevant regulatory barriers hampering a further diffusion of residential storage systems. During this first scoping phase, the research focused on institutional work carried out by actors of the electricity and automotive sector (Käsbohrer et al., 2024).

In our deep dive phase (between May 2023 and September 2024, 8 interviews), we asked interviewees about specific challenges emerging in the acceleration phase. We were guided by the acceleration challenges identified in the literature, but also open to case-specific nuances in a more inductive manner. As regards roles, we asked interviewees about their perceived roles in aligning regulation without sticking solely to theory-led categories. In a similar vein, further

[29] Three interviews during the scoping phase were conducted by the first and third author, while the remainder of the interviews were solely conducted by the first author. Four interviews are follow-up interviews with an interviewee who was interviewed for the second time. The participant observation was carried out by the first author.

questions targeted interviewees' perception about lacking and existing abilities and resources as well as their relevance for tackling acceleration challenges by adapting regulation.

Table 13: Interviews in scoping and deep dive phase.

Scoping phase: February 2021 - April 2023		
31 Interviews with experts from: industry associations (6), storages manufacturers (3), electricity providers (3), companies focusing on energy managements systems (2), automotive supplier representative (1), DSOs (2), TSO (1), lawyers (2), researchers (2), research institute (2), Chamber of Commerce and Industry (1), State Network Agencies (2), Federal Network Agency BNetzA (1), Ministry for Economic Affairs and Climate Action BMWK (1)		
Deep dive phase: May 2023 - September 2024	**Date**	**Duration**
Industry association representative (energy sector)	May 2023	69 min.
Ministry for Economic Affairs and Climate Action (BMWK): Civil servant	Nov 2023	70 min.
Ministry for Economic Affairs and Climate Action (BMWK): Civil servant	May 2024	20 min.
Industry association executive director (energy sector)	May 2024	67 min.
Ministry for Economic Affairs and Climate Action (BMWK): Civil servant	June 2024	38 min.
Federal advisory authority in the field of charging infrastructure	June 2024	45 min.
State Network Agency representative	Aug 2024	37 min.
Federal Network Agency representative (BNetzA)	Sept 2024	72 min.

Source: own elaboration.

The interview transcripts and notes taken during the participant observation were coded in MaxQDA to perform a qualitative content analysis. The coding scheme was informed by the analytical framework, but also enriched through insights from the empirical material (Siggelkow, 2007; Mayring and Fenzl, 2019, for the coding scheme and number of coded text passages see Appendix P, for exemplary quotes see Appendix Q). First, we coded the material according to all acceleration challenges, as derived from the literature, but with special focus on regulatory implications. Second, we conducted a bottom-up coding of the regulatory state capacities for coping with these challenges (both required and missing). During the coding process, we applied the change in government as analytical lense with the purpose of unveiling if concomitant changes in state capacities resulted in regulatory changes. In order to increase the validity of our findings, we cross-validated statements of interviewees amongst each other, including among different experts affiliated to the same organisation or department.

7.4 Findings

We start the findings section by elaborating on the institutional context of energy regulation in Germany (in section 7.4.1), before moving on to the challenges and regulatory implications slowing down the diffusion of residential storage systems (in section 7.4.2). Regarding regulatory state capacities for tackling these challenges, our analysis reveals two main phases, which differ in the focus of institutional work: maintaining (in section 7.4.3) and creating (in section 4.4). We conclude the findings section with a synopsis table (in section 7.4.5).

7.4.1 Institutional context: German energy regulation

The Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz*, EEG) and the Energy Industry Act (*Energiewirtschaftsgesetz*, EnWG) set the market design of the German electricity system including the promotion of renewable energies. As the primary legislation regulating

the German electricity market, the EEG and EnWG define market roles in the electricity system (production, consumption, transport), differentiate between types of electricity (conventional and green), set measurement requirements, declare exemptions of grid fees, taxes, and surcharges, and regulate grid access for electrical loads, such as storage systems.

As regards amending the central legislation, formal decision-making power lies with the German federal parliament. The substantive work on the legislation is mainly the responsibility of the Ministry for Economic Affairs and Climate Action (BMWK). The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (BNetzA) serves as downstream executive authority, mandated with guaranteeing the liberalisation and deregulation of the electricity market via non-discriminatory network access and efficient system charges (BNetzA, 2024). Associated with a high level of expertise and commitment, BNetzA representatives are involved in amendments of EEG and EnWG in close collaboration with the BMWK. Thus, we focus on these two governing entities when unpacking regulatory changes and the associated state capacities.

7.4.2 Acceleration challenges and regulatory implications: Residential storages in the German electricity system

The accelerated diffusion of residential storage systems in Germany faces four main obstacles, which can be traced back to various interacting acceleration challenges.

First, in order to avoid critical grid conditions through storing electricity, a better system integration through front-of-the-meter services is needed [1-WHO]. This refers to the controllability of photovoltaics and residential storage systems and to the sale of surplus electricity on the electricity exchange according to price signals through a third-party marketer (‘Direktvermarktung’) in order to prevent photovoltaics from feeding in maximum electricity at midday and to facilitate the feeding in of electricity into the grid in times of low grid voltage. However, our empirical material suggests that only a small part of residential storage systems works in a system-integrating manner beyond mere behind-the-meter storing of self-produced electricity for a later usage. Being further electrical loads, electric vehicles and heat pumps reinforce this issue, but also enhance the potential of storage systems in mitigating critical grid conditions, due to a several times higher storage capacity [2-MSI]. The main reasons for this missing system integration are linked to system governance [8-GOV] and its implications: the delayed rollout of smart-meter-gateways, the missing digitalisation of low-voltage grids and the mandatory separation of green and conventional grid power leading to complex metering requirements since the different electricity flows are associated with different subsidies, taxes and fees respectively (§ 19 EEG).

Second, the amendments of the EEG and EnWG are highly contested [4-EXP]. Interviewees mention industry associations, consumer organisations, industry stakeholders from the electricity and (increasingly) mobility system, and parliamentarians as main contestants. Whereas the legal environment of EEG and EnWG allows for an enhanced self-consumption share through storage, contestation revolves around a number of issues. First, the above-mentioned compulsory separation of conventional and green electricity hinders grid services (frequency containment reserve). Second, introducing a legally binding definition of storing electricity would exempt storages from grid fees and surcharges. Third, the introduction of industry standards is often contested, too, as they can influence future business models or market success. For instance, communication interfaces for public charging determine who is in a better position to

handle the payment process. Fourth, tax and surcharge burdens still hamper energy communities including energy sharing. Fifth, regulation on bidirectional charging including grid charging periods of private electric vehicles, which also affects residential storage systems (§ 14a EnWG), is missing. In this context, justice-related concerns are reflected in regulation, as interviewees of regulatory agencies highlight a fair distribution of fees and charges as well as costs for grid expansion, also including owners of residential storages [6- JUS]. Furthermore, multi-system interactions reinforce this contestation, since the automotive industry is intensifying their advocacy work towards BMWK and BNetzA, such as regarding the grid-oriented controllability of storages and electric vehicles. For example, in 2021, after an intervention of an automotive industry association, a draft law (§ 14a EnWG) was cancelled, which would have authorised DSOs to control charging periods of private electric vehicles and residential storage systems and, thus, would have prevented customers from flexibly connecting their appliances to the grid [2-MSI]. Against this backdrop, industry stakeholders and representatives of regulatory agencies note that the accommodation of particular interests is one reason for the high complexity of German energy regulation and potentially delayed regulatory changes [3-DEC].

Third, industry stakeholders allege EU legislation, which fosters the self-consumption of electricity and energy sharing, and which needs to be transposed into member states' regulation [8-GOV]. While industry stakeholders emphasise a lack of implementation of EU legislation (e.g., reliefs for fees and charges particularly for energy communities, reducing bureaucracy and metering requirements), BMWK and BNetzA representatives point to ambiguities and vagueness with respect to residential storages in EU legislation (e.g., regarding grid fees, definition of storages). Futhermore, they criticise in particular industry associations for not clearly outlining inconsistencies [4-EXP].

Fourth, industry experts criticise governing entities, in particular the BNetzA, for not having acknowledged the emotional motivation of consumers for a long time. According to almost all interviewees, emotional aspects like a fascination for the technology or enhancing a user's degree of autarky with self-produced electricity motivates consumers to buy storages, electric vehicles, and heat pumps. Notwithstanding, when it comes to behavioural change, an industry association representative and a BNetzA representative emphasised the importance of an appropriate pace of change, as too far-reaching obligations or too many amendments are likely to trigger a rather defensive attitude of future consumers [5-CON].

7.4.3 First period: Institutional work focusing on 'maintaining'

Especially under the last Merkel government, industry stakeholders have criticised the regulatory environment for obstructing a more profitable realisation of business models involving residential storages and rather maintaining a status-quo.

From a whole-system perspective [1-WHO], our empirical material reveals an often critical attitude towards residential storage systems in BMWK and BNetzA [*cultural resources*]. In 2021, a BMWK representative stated that opinions on the potential of residential storage systems vary very strongly across BMWK employees. Thereby, the arguments against storage systems are usually of a technocratic nature. For instance, in 2021, a BNetzA representative emphasised that residential storages hamper households' predictability and controllability. Furthermore, the interviewee questioned their need and profitability and rather pleaded in favour of a full feed-in of self-produced electricity, drawing on the arguments of following market

signals in an efficient way and of a truecost pricing of net electricity with grid fees, since electricity has to be fully available at any time in spite of residential storage systems [3- DEC]. In this context, representatives of both entities emphasise the need to *warn* of and *mitigate* the potentially negative effects of storages for end consumer in terms of fees and charges [6-JUS].

As regards the above mentioned resistance [3-DEC] and contestations [4-EXP], the roles of *moderator* and *gatekeeper* along with *political abilities and human resources* are highly relevant for handling divergent interests and advocacy work including public (associations') hearings, the publication of (draft) legislation, and the incorporation of feedback of industry stakeholders (e.g., position papers). In *operational* terms, industry stakeholders emphasise too short deadlines, for example for associations to write position papers regarding draft legislation. Representatives of BMWK and BNetzA admit this problem and argue with their workload. By contrast, BMWK and BnetzA interviewees highlight the challenge of having sufficient *knowledge* and *analytical abilities* for aligning regulation to emerging business models given their perception of an insufficient clarification of business models and regulatory barriers by industry experts and particularly industry associations.

Table 14: Main regulatory changes through amendments of EEG and EnWG affecting the market for residential storage systems in Germany under the Merkel government (2018-2021).

Main regulatory changes affecting residential storage systems under the Merkel government 2018-2021 (with Peter Altmeier from the CDU as economics minister)[30]	
EEG 2021	▪ Easier grid access for storage systems (§8 Abs. 5 S. 3 EEG). ▪ Threshold for exemptions of grid fees, taxes and surcharges set from 10 kWh to 30 kWh for new and existing installations (§ 61 Abs. 1 EEG) (as required by EU regulation), thus, avoiding de-facto double charging with grid fees, taxes and (EEG-) surcharges for installations < 30 kWh in the course of storing and withdrawing electricity from the storage (grid services) due to high and complex measurement requirements (§§ 60, 61l EEG). ▪ § 61l EEG simplified, grid services involving storing and withdrawing electricity from the storage possible for prosumers without double charging with taxes and (EEG-) surcharges. (*However, not applied to grid fees and still highly complex in terms of measurement requirements).* ▪ Joint production and usage of renewables by self-consumers located in the same building (landlord-to-tenant electricity) facilitated, as electricity can be delivered by a third party instead of the facility operator itself (§ 21 Abs. 3 EEG). Furthermore, higher government subsidies for projects in rental apartments (§ 48 EEG).
EnWG 2021	▪ Fees and charges (§ 19 Abs. 2 EnWG, § 17f Abs. 5 EnWG 'offshore grid fee' § 48 EnWG 'concession fee') measured analogously to § 61l EEG. (*However, not applied to grid fees § 118 Abs. 6 EnWG).*

Source: Erneuerbare-Energien-Gesetz (EEG) in Clearingstelle (2025b); Energiewirtschaftsgesetz (EnWG) in Clearingstelle (2025e).

Concerning the implementation of EU legislation [8-GOV], *moderators* are needed for both vertical and horizontal *coordination*. This includes communicating national interests in consultation with the Federal Government towards the EU level [*vertical coordination*]. Furthermore, a BMWK representative highlights the challenge of examining very detailed EU legislation and

[30] The full name of the economics ministry at this time was Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy, BMWi) – for simplicity, we refer to it as BMWK in the text. The EEG amendment came into force in January 2021, the EnWG amendment in July 2021.

identifying potential inconsistencies with national regulation, which requires *analytical abilities*, *knowledge* and *human resources*. Similarly, consensus-building across ministries and departments and a non-compartmentalised *horizontal coordination* of regulation is necessary, since emerging use cases including public and private charging have to be aligned with basic principles of energy regulation (separation of electricity flows). Furthermore, transnationally valid cross-system elements, like communication interfaces and smart-meter gateways, need to be standardised. In this context, representatives of BMWK and BNetzA highlight the close collaboration between both entities, but mention difficulties regarding, for instance, the Federal Ministry for the Environment. Furthermore, interviewees from both the industry side and of regulatory agencies attribute the delayed rollout of smart-meter gateways to *coordination* failures between BMWK and the Federal Office for Information Security involved in the standardisation process.

The amendments of EEG and EnWG in 2021 showed changes, however, mainly complying with the requirements of EU legislation and rather small-scale, incremental in nature (see Table 14).

7.4.4 Second period: Institutional work shifting to a focus on 'creating'

The introduction of the new Scholz government[31] in the end of 2021 marks a change in the institutional work carried out by BMWK and BNetzA towards creating the new rules of the game. The government's aim of expanding residential photovoltaics triggers the will to integrate electrical loads into the electricity system in a grid-friendly manner for avoiding critical grid conditions. Thus, the grid-friendly system integration is almost unanimously recognised on the agenda in both institutions [*learning*, 1-WHO].

As regards whole system change [1-WHO], BMWK representatives describe their role as *facilitating* and *promoting* the expansion of photovoltaics and residential storages by using their *mandate resources* to increase the photovoltaic expansion path and removing regulatory barriers for the system integration of all storage types (residential, mobile, large scale, pumped storage hydro power stations). Thereby, BMWK representatives emphasise the aim of a viable overall system optimum, level playing fields for the different storage technologies in terms of fees and charges [6-JUS] and reducing the high complexity of German energy regulation. In this context, they emphasise the need to avoid the accommodation of particular interests such as unjust privileges regarding fees and charges or unfair standards, which requires *knowledge and human resources* as well as *analytical abilities* [3-DEC].

The BNetzA has been *observing* the critical grid conditions associated with the midday peak of photovoltaics and *warning* of potential blackouts. In this context, in 2024, a BNetzA representative (the same expert that has been interviewed in 2021 already) stated that the potential of front-of-the-meter business models involving residential storages, electric vehicles, and heat pumps for flexibilising electrical load and generation and containing these critical grid conditions has been underestimated for a long time [*learning and reflexivity*]. Hence, while in charge of the detailed technical design of metering requirements and grid fees, the BNetzA has started to work on a less stringent model for metering green and conventional power for mitigating this

[31] The Scholz government with its so called 'traffic light' coalition between Social Democrats (SPD), Greens (Bündnis 90 / Grüne) and Liberal Democrats (FDP) began government work in December 2021.

problem [*cultural resources*]. In this context, the BNetzA representative further points to challenges in communicating draft regulation and amendments towards industry experts, politics and the public, given a declining legitimacy after various already conducted amendments [*legitimacy resources*; 5-CON].

As regards multi-system interactions [2-MSI], a new BMWK department for the system integration of electric vehicles, heat pumps and storage systems, a consulting agency on e-mobility and charging (NOW GmbH), and new meeting formats, such as working groups between economics and transport ministries (BMWK and BMDV), have been initiated [*coordination and operational abilities*]. Moreover, new BMWK employees experienced in this field were hired in the wake of the change of government [*human and network resources*]. Thus, there has been an increase in *knowledge and analytical abilities* on interface aspects, such as bidirectional charging [*learning*]. However, industry stakeholders criticise the to some extent still prevailing reluctance and silo mentality separating, for instance, electricity and mobility related issues, instead of defining overall visions and guidance (also in the sense of educating the public) towards a broad reconceptualisation of the electricity market including cross-system regulation [*cultural resources*; 5-CON]

Table 15: Main regulatory changes through amendments of EEG and EnWG affecting the market for residential storage systems in Germany under the Scholz government (2021 – 2025).

Main regulatory changes affecting residential storage systems under the Scholz government 2021-2025 (with Robert Habeck from the Greens as economics minister)[32]	
EEG 2023	▪ Suspension of EEG surcharge (§ 58 EEG). ▪ Significant increase in the annual expansion path of solar PV ▪ Simplified measurement at grid connection point (behind-the-meter): most fees and taxes only relate to withdrawals from and feed-ins of electricity to the grid, balancing of electricity flows (acc. to §21 EnFG 'Energiefinanzierungsgesetz', former § 61l EEG). (*However, still contested: grid fees and electricity taxes in multi-use applications)* ▪ Storage losses are exempt from charges and fees (§ 21 EnFG). ▪ New rates of feed-in compensations for prosumers completely and partly feeding in (involving self-consumption) with the latter being reasonably high and, thus, enhancing the installation of a storage system in addition to photovoltaics (§ 100 Abs. 4 EEG).
EnWG 2022	▪ New definition of 'storage' as new category besides generation, transport and consumption (§3 Abs.15d EnWG).

Source: Erneuerbare-Energien-Gesetz (EEG) in Bundesministerium der Justiz (2023b) and Clearingstelle (2025a); Energiewirtschaftsgesetz (EnWG) in Bundesministerium der Justiz (2023a) and Clearingstelle (2025d)

Regarding concrete regulatory changes, BMWK and BNetzA interviewees and further industry stakeholders emphasise that far-reaching regulatory changes have been advocated by the new government, in particular by the FDP's parliamentary group (see Table 15). Flexible electricity tariffs, the above-mentioned separation of green and conventional electricity as well as enabling energy communities are topics that are currently being worked on.

[32] The full name of the economics ministry at this time was Federal Ministry for Economic Affairs and Climate Action (BMWK). The EEG amendment came into force in January 2023, the EnWG amendment in December 2023.

7.4.5 Synopsis of findings

Table 16 provides an overview of our findings on the required regulatory state capacity (on the right) arising from the regulary implications of the acceleration challenges (on the left) in Germany's energy transition. In the table, we focus on unpacking the roles, abilities and resources needed for tackling regulatory change meant to address the various types of acceleration challenges.

Table 16: Challenge-specific regulatory implications in accelerating net-zero transitions and required roles, abilities and resources for coping with these challenges.

Acceleration challenge	Regulatory implications	Required regulatory state capacity
(1) Whole system change	1. Aligning regulation with whole system change instead of integrating single innovations in existing regulatory frameworks: Introducing new system roles/elements (storages as system element), regulation of infrastructure, standards (e.g., communication interfaces, charging infrastructure, smart-meter) 2. Defining and facilitating a viable overall system optimum instead of individual optimum (grid-friendly integration of residential storages) 3. Avoidance of regulatory complexity and inconsistencies (e.g., regulation on metrology) 4. Level playing field for different technologies (e.g., in terms of fees and charges, and grid connection requests)	**Roles: facilitator, promotor, warner, observer, mitigator** **Abilities: analytical** (understanding up-to-date developments regarding markets, technologies, business models etc. as well as interplay of elements), **learning and reflexivity** (understanding and re-evaluating potential of storage systems) **Resources: human** (man power for designing regulation), **knowledge** (regarding markets, technologies)**, network** (non-compartmentalised working culture)**, cultural** (critical attitutude, less stringent metering requirements), **mandate** ('license' to increase the photovoltaic expansion path)
(2) Multi-system interactions	1. Non-compartmentalised, integral regulatory changes (e.g., grid integration of interface business models) 2. Handling institutional work from new systems (e.g, advocacy stemming from the automotive system) 3. Fair market conditions for all systems involved (e.g., avoiding accommodating particular interests) 4. Standardisation of cross-system elements (e.g., metering requirements and smart meter for residential and mobile storages; communication interfaces)	**Roles: moderator, gate keeper** **Abilities: Political** (handling advocacy work of actors associated with different systems), **analytical and learning** (understanding of cross-system technologies, business models, standards etc.), **coordination** (better inter-organisational collaboration), **operational** (new entities at the interface of systems, harmonising cross-system technologies and standards, e.g., smart-meter) **Resources: knowledge** (on multi-system interactions)**, network** (new interaction formats)**, human** (time consuming interaction with new stakeholders from different systems), **cultural** (visionary thinking, overcoming silo mentality)
(3) Decline and resistance	1. Support structural change by phasing out regulation (e.g., suspension of EEG-surcharge) 2. Abolishing former particular privileges (e.g., regarding fees and charges)	**Roles: facilitator** **Abilities: political** (moderating incumbent interests, overcoming contestation), **learning** (reevaluating technologies and business models); **analytical** (advocacy work, such as position papers, needs to be analyzed regarding particular interests **Resources: Human** (handling advocacy work); **knowledge** (for identifying particular interests); **cultural** (critical attitutude, less stringent metering requirements)

Acceleration challenge	Regulatory implications	Required regulatory state capacity
(4) Expansion and contestation	1. Moderating regulatory changes in the context of vested interests and political contestation stemming from different stakeholders (e.g., contestation around fees, charges, taxes, data access, product and green finance standards), avoiding the accommodation of particular interests 2. Handling internal contestation around technological trajectories (e.g., heterogeneous attitudes towards different storage technologies)	**Roles: moderator, gate keeper** **Abilities: Analytical** (for aligning regulation to emerging business models; advocacy work, such as position papers, needs to be analyzed regarding particular interests); **Political** (handling advocacy work of different stakeholders, communicating draft amendments); **Operational** (processes enabling stakeholder involvement such as appropriate deadlines) **Resources: Human** (handling advocacy work)**, knowledge** (on business models and interests), **legitimacy** (communicating regulation and amendments)
(5) Consumer practices & routines	1. Regulation enabling adoption of technologies and business models (e.g., prosuming, energy communities), 2. Regulation enabling behavioural change (e.g., bi-directional charging), reassuring an appropriate pace of change	**Roles: facilitator, promoter** **Abilities: Analytical** (understanding the motivation of consumers; finding an appropriate pace of change/avoding too far-reaching obligations potentially triggering a defensive attitued) **Resources: Legitimacy** (educating and communicating amendments to the public)
(6) Justice	1. Including a broad justice approach in evaluating regulation regarding end users (e.g., tailor regulation to low-income households: fees and charges need to be fairly distributed) 2. Fair market conditions for all technologies and systems involved (see 2-Multi-system interactions) (e.g., regulation, such as communication standards, may not favour systems/actor groups)	**Roles: observer, mitigator, warner** **Abilities: analytical** (assessing justice related aspects, e.g. market conditions, conditions of user groups); **political** (communicating justice related concerns; equal treatment of all user groups and technologies) **Resources: knowledge** (designing non-discriminatory conditions for all user groups and technologies)
(7) International dynamics	1. Aligning regulation with transnationally valid policies (e.g., EU legislation needs to be transposed to the national scale); 2. Transnationally valid standards (e.g., transnationally harmonised smart-meters and communication standards, for example, for charging)	**Roles: moderator** **Abilities: analytical** (analysing EU legislation); **coordination** (inter-organisational cooperation across compartments and scales) **Resources: human** (integrating and coordination integration of EU legislation), **knowledge** (familiarity with EU regulation
(8) Governance	1. Stronger vertical coordination required across spatial scales (e.g., transposing supranational regulation into national level and communicating national interests to supranational level); 2. Stronger horizontal coordination required due to cross-system business models, standards (e.g., smart meters) 3. Consistent and coherent regulation across levels and systems required.	**Roles: moderator** **Abilities: political** (solving tensions between organisations), **analytical** (analysing EU legislation); **coordination** (vertical and horizontal inter-organisational cooperation across compartments and scales); **Resources: human** (integrating and coordination integration of EU legislation), **knowledge** (getting familiar with EU regulation), **mandate** (clear responsibilities for implementing EU legislation)

Source: Own elaboration.

7.5 Discussion

7.5.1 Interplay of regulatory implications of acceleration challenges and required regulatory state capacity

Given our focus on regulation as one specific type of policies, we were able to derive four overarching regulatory implications resulting from acceleration challenges, thereby deepening existing insights on general policy implications arising from such challenges in the acceleration phase of net-zero transitions (see Table 11 in section 7.2.1).

First, our case reveals that major regulatory change is required but hindered by a high degree of *institutionalisation*. Indeed, regulation sets the basic, overarching rules of the game, which in our case constitute the electricity market design. Against this backdrop, we find that unfolding 'whole system change' is one of the key acceleration challenges affecting regulation and regulators. More specifically, storage systems – mainly used for storing self-generated electricity for later use – need to be integrated into the electricity market design in a grid-oriented way. Thereby, basic principles are affected and need to be adapted (e.g., metrological separation of electricity flows, grid fees and charges). In this context, introducing new technologies or new legal roles, like the storing of electricity, constitutes a major endeavour, since these basic principles and rules are highly institutionalised, and also shaped by exemptions and particular privileges. Given the associated politics of accelerating transitions resulting from path dependencies and resistance from vested interests, which is also referred to as "capture" in regulation theory (Breyer, 1982), we find initially rather incremental updates instead of major reforms, which, however, would be necessary for accelerating net-zero transitions. Such major electricity market reform is a key role for regulators, and requires not only high analytical but also strong political abilities.

Second, what complicates things further is that these long lasting, highly institutionalised rules governing the electricity market are characterised by high and ever increasing *complexity*. As proposed by Baldwin et al. (2012), infrequent revisions and the failure to prune regulations has led to an ever-denser thicket of rules. Our interviewees – both industry experts and regulators – confirm the high complexity of the German electricity market design, which poses regulators with the challenge of ensuring consistency in the regulatory mix as part of the wider policy mix. For instance, our empirical material revealed inconsistencies between the EEG and the regulation for measuring point operation. Avoiding such inconsistences requires a high level of human and knowledge resources as well as enhanced analytical and coordination abilities.

Third, we find a high degree of *contestation* around setting the new rules of the game for expanding the net-zero trajectory, which regulators must navigate. As already suggested by Rogge and Goedeking (2024) in the context of the electrification of transport, this acceleration challenge of 'expansion and contestation' plays a critical role in our case of residential storage, too, and also interacts with other challenge types, in particular 'governance', 'justice' and 'multi-system interactions'. Advocacy work revolves around the argument of Germany not having implemented EU legislation, which demands exemptions from fees and charges for electricity storage solutions. In response, regulators point to inconsistent EU legislation. In addition, regulators consider ensuring 'justice' as their duty and, thus, argue with just fees and charges for every electrical load connected to the grid. Furthermore, the increasing advocacy work carried out by stakeholders belonging to the mobility system requires regulators to expand their knowledge resources and analytical abilities to the new reality of 'multi-system interactions'.

Examples are the contestation around the controllability of electrical loads such as electric vehicles and storage systems or standards and communication interfaces regulating payment transactions for vehicle charging. Taken together, the crosscutting nature of contestations in the expanding trajectory reinforces the relevance of political abilities as important aspect of regulatory state capacity.

Fourth, our case highlights the *accelerating effect of multi-system interactions*. The scholarship on multi-system interactions suggests that complementary technologies can accelerate transitions, due to, for instance, alignments in institutional work carried out by actors from multiple system or cross-system user learning (e.g., Andersen and Geels, 2023; Rosenbloom, 2019). Our results suggest that this also holds true for the governance dimension, as electric mobility reinforces the awareness of critical grid conditions within governing entities and enhances the potential of business models including residential storage systems and electric vehicles in mitigating this issue. However, designing multi-system regulation, which takes advantage of the potential of multi-system business models, requires greater non-compartmentalised coordination as part of regulatory state capacity

7.5.2 Enhancing regulatory capacity for acceleration: From ‘maintaining’ to ‘creating’

Based on these four regulatory implications and our further findings, we argue that regulators need to enhance their regulatory capacity – the specific interplay of roles, abilities and resources – to be able to tackle the challenges arising in the acceleration phase of net-zero transitions. While in early phases of such socio-technical transitions, the roles of promoter, initiator and lead user are crucial (Borrás et al., 2024), for instance by introducing standards for innovations, our findings emphasise the roles of moderator and gate keeper as well as observer, warner and mititgator for aligning regulation in the acceleration phase. In light of multi-system interactions, the highly contested amendments require governing entities to moderate between divergent interests and to fill a gatekeeper role assuring equal access for all relevant actors (Käsbohrer et al., 2024). For example, as shown by the cancelled draft law on the controllability of electrical loads (§14a EnWG), enhanced political abilities are necessary for moving forward, in particular, regarding stakeholder engagement and consensus building. In addition, analytical and learning abilities accompanied by knowledge resources are relevant for scrutinising particular interests and for understanding market dynamics and the effects of regulatory changes on business models in the sense of a co-evolution between policymaking and socio-technical change (Edmondson et al., 2019).

Correspondingly, our case study reveals highly dynamic regulatory state capacities and more radical regulatory changes in the second period. Indeed, almost all interviewees from both industry organisations, regulatory agencies and the BMWK emphasise the driving influence of the new government coming into office at the end of 2021, referring to a stronger ‘political will’ to accelerate the net-zero energy transition in Germany. Our framework helps us to explain these accelerating dynamics by identifying changes in roles, resources and abilities, differentiating between the ministry in charge (BMWK, led by the Green Party) and its regulatory agency (BNetzA).

Regarding the former, we find three major changes with the Ministry for Economic Affairs and Climate Action (BMWK). First, the personnel in BMWK has been increased, hiring further employees experienced in the field of renewables and storage technologies, leading to an increased knowledge on the potentials of residential storages. Second, in operational terms, new departments, procedures and meeting formats have been established enhancing the network resources of employees. Third, the higher level of 'political will' serves as a resource in the form of a strong political mandate establishing clear and ambitious targets, with policy and regulatory change leading to an increase in its legitimacy as additional resource. More specifically, the target of the new BMWK leadership to promote photovoltaics led to a re-evaluation of storage systems as complementary technology necessary for the system integration of residential photovoltaic systems. Taken together, the example of the BMWK shows how regulatory state capacity can be built from inside the organisation itself after a change in political leadership.

Regarding the latter, we find that the Federal Network Agency (BNetzA) is characterised by a form of public leadership, which leaves it with more room for maneuver despite changes in governments. However, while more independent from political trends and usually arguing based on technocratic arguments, the regulatory agency BNetzA also underwent a change in their regulatory state capacity from a rather critical attitude towards storage systems to one of promoting and facilitating their system integration by means of drafting regulatory amendments therefore. Importantly, its role itself facilitated this change. As observer, warner and mitigator, the changing socio-technical environment rather than internal changes have been the driving force for this change in roles, in particular the critical grid conditions due to expanding residential photovoltaics and the growing potential of front-of-the-meter services involving photovoltaics, storages and electric vehicles in mitigating this issue. Thus, a BNetzA representative pointed to learning and reflexivity having occurred over time; recognising that the potential of storage systems in contributing to a secure electricity supply has long been underestimated. In conclusion, the regulator with its legislative influence arising from its legitimacy due to expertise and experience, is crucial for regulatory change needed for the acceleration of net-zero transitions.

7.5.3 Policy implications for accelerating net-zero transitions through regulatory change

While the German context might show some peculiarities, such as the strong prevalence of residential photovoltaics or the nuclear phase-out and thus reliance on a high share of renewables in the future net-zero electricity system, we still derive five more general recommendations for policymaking and in particular for regulators and their regulatory state capacity for accelerating net-zero transitions.

First, by assigning regulators with a new role to proactively redesign the electricity market to make it fit for the net-zero future early on, such transitions can be accelerated. While the challenge of 'whole system change' is unique to the acceleration phase, taking account of a grid-oriented integration of storage systems into the electricity system already in the emergence phase would have accelerated their diffusion. As our case has shown, the re-evaluation of storage systems as mitigatory technology for critical grid conditions enhanced the endeavours for regulatory changes, but if this would happen earlier in less advanced jurisdictions, socio-technical change could be accelerated there.

Second, we find a crucial role for learning abilities in regulatory state capacity. In this regard, we argue that the openness for learning should be actively pursued and, if possible, fostered by operational procedures, such as non-compartmentalised information exchange. This in turn may help with the reorientation of roles and resulting regulatory change fostering the acceleration of net-zero energy transitions.

Third, communication deficits as prerequisite for better coordination should be addressed, thereby tackling a potential barrier to political consensus – in two ways: on the one hand, regulators complained that industry experts and associations do not communicate innovative business models along with the respective regulatory barriers with sufficient clarity; on the other hand, industry stakeholders criticised the regulators for the high complexity and thus incomprehensibility of regulation.

Fourth, in response, regulators should strive for reducing regulatory complexity, particularly associated with the electricity market design, as overarching design principle in policymaking. Our empirical material suggests that the high complexity of regulation delays or even prevents the regulatory task of reconceptualising the electricity market design. Regulators should not shy away from more radical steps, even if this no longer serves particular interests.

Finally, regulators should strive to mitigate potential uncertainties in markets, such as regarding their perceived need for a front-of-the-meter system integration of photovoltaics and residential storage systems and the remuneration of grid services, instead of evoking further uncertainty. In order to ensure investment reliability, regulators may aim at a clear regulation for the use cases of new technologies (e.g., grid services) and avoid numerous and inconsistent amendments or uncertainties in mandated responsibilities

7.6 Conclusion

The paper in hand has addressed the question of what regulatory state capacity is necessary to tackle regulatory implications unique to the acceleration phase of net-zero energy transitions, thereby bridging the literature on acceleration challenges and policy implications with the literature on transformative capacities. Based on a narrow understanding of regulation as one specific type of policies, we derive regulatory implications resulting from acceleration challenges and investigated the necessary regulatory state capacity by differentiating between roles, abilities and resources. The resulting analytical framework is applied to the market for residential storages systems in Germany.

Our findings reveal the relevance of the challenges ‘whole system change’ and ‘expansion and contestation’. The importance of the former results from the need of integrating storage systems into the electricity system for mitigating critical grid conditions due to expanding residential photovoltaics. Thereby, learning and reflexivity led to a re-evaluation of storage systems. ‘Expansion and contestation’ is a cross-cutting challenge interacting with the coordination challenge of implementing EU legislation and multi-system interactions given divergent interests and advocacy work stemming from multiple systems. Correspondingly, the roles of gatekeeper and moderator as well as political abilities are of high relevance. While the changing attitude towards residential storages in the BNetzA is based on its role as observer, warner and mitigator embedded in a changing socio-technical environment, the changing regulatory capacity in the BMWK is triggered by the change in leadership built from inside the organisation itself.

A limitation of our case study lies in establishing causality between regulatory capacities and regulatory change, given, for instance, the delayed introduction of smart meters hampering the system integration of storage systems as rival explanation. Furthermore, given our focus on the organisational level of regulatory state capacity, the interplay with the systemic and individual level of such capacity warrants future research. Future research could also extend our analytical framework to address not only regulatory change and regulatory state capacity, but to investigate policy change and required state capacities for policy makers changing policy mixes composed of different types of instruments to tackle acceleration challenges. Finally, in light of the unique socio-political context of German electricity regulation, the framework would benefit from being applied to other institutional architectures, like a stronger intertwining of regulation and market-based instruments, and sectors with other characteristics, such as a stronger influence of international dynamics. Notwithstanding, our research has revealed important overarching insights and key policy implications of relevance for facilitating regulatory change as lever for accelerating net-zero energy transitions.

PART 3: Umbrella II

8 Discussion and outlook

The final chapter of this thesis will first discuss overarching findings from this research and its contribution to current debates in transition studies. The second subsection reflects on avenues for future research inspired by the empirical material. The concluding remarks end this thesis.

8.1 Discussion of findings

I have identified the following three arguments, which will be discussed subsequently, as my overarching findings. First, I have observed a change in the configurations of relevant actors involved in inducing institutional changes. Second, it is necessary to adopt a more nuanced perspective on incumbency, as particularly regulators are considered responsible for impeding the diffusion of residential storage systems and finally for creating a beneficial regulatory environment. Third, I reflect on structural conditions for institutional work. Lastly and more generally, I briefly reflect on the multifactorial causal arrangement of events and conditions affecting transition dynamics in this case.

8.1.1 Changing actor configurations

The changing configurations of actors advocating residential storage systems in Germany have been evident throughout the entire empirical period and across the individual articles. Pilot interviews, which I conducted for writing the research proposal for this thesis in 2018, and the first interviews of the project phase in early 2021 indicate that particularly niche players dominated the market in its initial phase. Especially medium-sized storage manufacturers (e.g., *sonnen GmbH, SENEC GmbH, E3/DC*) and various smaller providers of (mostly green) electricity offered solutions involving residential storage systems. The large electricity utilities (*RWE, Vattenfall, E.ON, EnBW*) were not among the pioneers of the early days (Zademach & Käsbohrer 2022; Käsbohrer & Zademach 2021; see also 3.2.1).

However, later interviews point to the growing influence of large electricity utilities and automobile manufacturers in launching business models based on residential storage systems (along with green electricity, charging hardware and electric vehicles; see also 3.2.2 and 3.2.3). Especially the conceptual approach of Article I including institutional work activities and the associated enabling conditions shows how incumbents are capable of leveraging their resources to integrate new technologies. This corresponds to contributions highlighting the reorientation capacities of incumbents (Hellsmark & Hansen 2020; Turnheim & Sovacool 2020; Steen & Weaver 2017; Bergek et al. 2013; see also section 2.1.2).

In this context, the embeddedness of actors in multiple systems (in this case electricity and automotive) is a novel aspect of this case study. Article I discusses the affiliation of powerful actors regarding their position between or within existing systems and highlights the strong agency of traditional industry associations and incumbent, established players (electricity utilities and automobile manufacturers including subsidiaries for charging), who use their sector-specific experiences and aim at gaining competences in the respective adjacent system.

Article II reinforces the agency of industry associations and established business players, such as electricity utilities, in the context of a multi-scalar arrangement. The results show that these actors, which have traditionally engaged in shaping regulations and discourses based on longstanding relationships to political institutions at a national scale, are also engaged in getting

access to EU level institutions and thereby shaping EU legislation and discourses. Both papers discuss the influence of the sectoral environment of electricity generation, which – not least in the German context (Meckling & Nahm 2018) – is characterised by strong regulation and, thus, strong agency for players with good access to political institutions, such as industry associations and major incumbents.

8.1.2 Nuancing incumbency

Speaking of actor configurations, this case study further allows for nuancing what constitutes incumbency in socio-technical configurations, which addresses recent claims for pluralising incumbencies in sustainability transitions (Turnheim & Sovacool 2020). According to Turnheim and Sovacool (2020), *"corporate firms or powerful governmental actors […] might be the most visible and usual protagonists of power concentration over socio-technical configurations*" in this regard. While my research does not confirm corporate firms as key incumbents in this case study, governmental actors have proven to be (considered as) incumbents. A large part of my interviewees suggests that BNetzA and BMWK oppose residential storage systems by delaying regulatory changes and not implementing EU legislation. However, as shown by Article II and III, national governmental authorities, in turn, highlight the lack of detail in EU legislation on residential storage systems. Other sector experts (e.g., industry associations) and regulators themselves also hold the high complexity of German regulation and the delayed introduction of digitally communicating smart meters responsible for the unused potential of residential storage systems. Hence, the empirical material indicates that incumbency is not solely shaped by a resisting attitude, but also by further, potentially hardly controllable factors.

Furthermore, Turnheim and Sovacool (2020, 182) emphasise *"the transient nature of incumbent positioning strategies and incumbencies themselves"* and call for more nuanced approaches towards the strategies of incumbents. They argue that the behaviours and strategies of incumbents are likely to change over time due to internal dynamics, such as organisational learning, or significantly changing transition contexts. Consequently, strategies arguably change from initial resistance and denial to exploration and re-orientation in light of economic, environmental or societal pressures. While many contributions shed light on the changing strategies of firms (e.g., Steen & Weaver 2017; Wesseling et al. 2015; Berggren et al. 2015; Bergek et al. 2013) or system changes influencing policymakers (e.g., Markard 2018; Turnheim & Geels 2013), Paper III discusses the changing attitudes of regulators in a more fine-grained manner. Drawing on the transformative capacity of regulators operationalised by means of their roles, abilities and resources, the research shows that the re-orientation towards fostering residential storage systems through regulatory amendments results, first, from changing system conditions along with reflexivity and learning. More precisely, residential storage systems can shave midday peaks of photovoltaic systems, which potentially result in critical grid conditions, which made the BNetzA reevaluate residential storage systems. Second, the new federal government taking office in 2021 with Bündnis 90/Die Grünen leading the BMWK resulted in a change in strategy and, thus, an expansion of photovoltaics along with storage systems.

As regards the influence of incumbents on transitions, Geels (2014) points to incumbents (firms and policymakers) in the UK electricity sector that mobilise instrumental, discursive, material, and institutional forms of power to resist climate change legislation. In her study on Danish waste management, Madsen (2022b) argues that Danish incumbent municipalities use their instrumental power by taking advantage of their affiliation with the government party, their discursive power asserting that Danish waste incineration is superior to the waste management of

other countries, and their material power by constructing pilot and demonstration plants for incorporating carbon capture and storage into incineration plants. My empirical material points to the institutional and discursive power of incumbent regulators. The institutional dimension is pertinent to regulatory agencies. As regards the discursive power, interviewees from BNetzA and BMWK themselves point to heterogeneous narratives around residential storage systems in both institutions, including a strong rejection of residential storages. Arguments brought forward against residential storage systems are mostly related to justice, such as a fair distribution of fees, charges and the costs of grid expansion, the affordability for low-income households, equal market conditions of multiple systems involved, or the high resource consumption related to the production of storage devices. In the initial market phase, especially the BNetzA communicated its critical attitude towards residential storage systems and its advocacy of large-scale market-based electricity trade to political parties, civil servants and the broader public.

8.1.3 Structural conditions for institutional work

When asked about obstacles to accelerating the diffusion of residential storage systems, almost all interviewed business stakeholders bring forward regulatory barriers and a negative narrative revolving around residential storage systems. The concept of institutional work operationalises the concrete actions and activities that actors carry out in order to induce institutional changes (Lawrence et al. 2009; Lawrence & Suddaby 2006). In this context, both Article I and II argue that these activities do not occur in a vacuum detached from structural circumstances. Instead, the articles take account of the recursive relation between structure and agency (Battilana et al. 2009; DiMaggio 1988). Hence, Article I focuses on the structural position of actors, in the sense of an actor's association with one or more socio-technical systems. Article II considers the scalar arrangement, i.e. structural conditions at the national and the EU scale, as a factor influencing institutional work. While not elaborating on institutional work practices per se, Article III sheds light on the regulatory context where this institutional work is actually taking place, namely regulatory agencies and their changing strategies. This echoes Fünfschilling (2019, 232), who argues that *"[a] particularly fruitful avenue for future research concerns the potential of structural preconditions, such as network constellations or regime structuration, to foster transformative processes"*.

Article I focuses on enabling conditions for institutional work operationalised by means of actors' resources, discourses, and social networks (Duygan et al. 2019). Duygan et al. (2019, 2021b) introduced these constituent elements that contextualise institutional work for uncovering the determinants that make an actor influential in inducing institutional changes in socio-technical systems. Swiss waste management served as an illustrative case showing which specific combinations of these endorsements (resources, discourses, social networks) are associated with high agency. Madsen et al. (2022) applied this heuristic to actor contestations within the Danish waste management. While aiming at foregrounding the specific sector characteristics of socio-technical systems, the authors shed light on the structural position of actors in the context of different emerging and established configurations in this system (e.g., incineration, landfilling, chemical recycling). In Article I of this thesis, the multi-system context is the specific feature of this case. The enabling conditions for institutional work according to Duygan et al. (2019) allow for scrutinising which actors and (sector-specific) endowments are associated with strong agency to shape institutions. Hence, it can be explained why and how traditional industry associations and incumbent, infrastructure-rich players (electricity utilities and auto-

mobile manufacturers including subsidiaries for charging) are able to draw on their sector-specific experiences (e.g., technological know-how in terms of digitalisation) and to gain knowledge in the respective adjacent system (e.g., regarding standards for controlling mobile and residential storages).

In Article II, the structural context of institutional work is conceptualised as a scalar arrangement, namely the national and the EU level, as actors carry out institutional work across scales aiming at the rescaling of institutional rationales. Thus, the contribution lies in analysing how scalar structures shape the purpose and possibilities of actors to change this scalar arrangement. Focusing on institutional structures, the article explains how scalar institutional conditions, such as institutional semi-coherence or expected and perceived narratives, can have a hindering or beneficial effect on rescaling.

8.1.4 Multiple causalities

Although adopting an institutional perspective arguably entails certain blind spots, such as the detailed technical innovation journey, my research has nevertheless revealed a multifactorial arrangement of conditions and events that affects the diffusion of residential storage systems in multiple ways. Article I highlights the specific context of multi-system interactions arguing that the agency of influential industry associations and car manufacturers results in a changing actor configuration and a stronger diffusion of residential storage systems. In Article II, the influence of EU legislation is emphasised with particularly national actors aiming to promote residential storage systems by advocating a thorough and quicker implementation of this EU legislation and inducing institutional changes at the European level. Article III focuses on the regulatory context arguing that the new government as well as changing system conditions have led to a changing attitude and, thus, changing regulatory state capacities in relevant institutions. Beyond that, the empirical material points to further conditions and events that play a role, such as the delayed introduction of smart meters, the high complexity of German energy regulation or the missing digitalisation of grids.

In light of these intersecting conditions and events, it might be difficult to identify immediate causalities. In this context, Turnheim and Geels (2013) refer to the discipline of history and historical explanation. Accordingly, explanations often entail conjunctures between multiple overlapping and intersecting processes as well as multidimensional, coevolving spillovers from external pressures (e.g., economic recession or user preferences). Moreover, instead of formal theory-testing designs, theories serve as conceptual themes and frameworks that trigger enquiries. In a longitudinal case study of the British coal industry (1913–1967), Turnheim and Geels (2013) emphasise that the destabilisation of the coal regimes has been the result of multiple pressures, spillovers and enduring trends (e.g., anti-smoke movement, coal-based alternatives, recession), which makes it difficult to assess the relative importance of each of these factors.

In the context of proving and falsifying theory through case study research, the economist Siggelkow (2007, 21) argues that theories and models are always simplifications. More specifically, the value of theories is to *"cut through idiosyncracies and unearth similarities across cases"*. Against this backdrop, he states that case study research has to be careful in not overdetermining a phenomenon, as many variables may appear to be crucial while investigating the details of a particular case. Instead, the value of useful theory is to rise above the idiosyncratic case, which demands choices and simplifications.

While writing the three individual articles, I found myself between these poles of abstracting empirical material through theory in order to elaborate on specific research questions on the one hand and tracing the multifactorial arrangements of overlapping and intersecting causes on the other hand. Each article addresses a particular research interest, which entails conceptual frameworks for making sense of the data, a focus on specific actor groups and, thus, on certain effects and conditions affecting the trajectory of transition dynamics. Yet, for instance, the rather slowly proceeding system integration of residential storage systems in Germany might not be the result of a critical attitude of regulators alone, but also induced by the missing digitalisation of grids, the high complexity of regulation or the delayed implementation of smart meters. In turn, these conditions might be brought about by preceding governance deficiencies. Against this backdrop, the individual articles take the multiple influencing factors into consideration, not least for the purpose of presenting rivalling, alternative explanations of empirical phenomena. At the same time, I aimed at providing detail and pursuing rigour in terms of theory and empirics by triangulating data sources and methods (see chapters 4.5.2 until 4.5.4).

8.2 Avenues for future research

When it comes to the impeding or facilitating effects of institutional conditions and in particular regulation on transitions, I have come across open questions that merit further attention. More specifically, I see potential in further addressing acceleration challenges of transitions and multi-system interactions as well as in bridging the debates on regulation and circular economies.

8.2.1 Acceleration challenges

I see particular potential for future research concerning the acceleration challenges of *consumers and social practices* and *justice*. First, the challenge of *consumers and social practices* addresses major changes in consumer practices and demand patterns, such as home charging instead of refuelling at petrol stations (Rogge & Goedeking 2024; Markard et al. 2020). As for residential storage systems, my empirical insights point to the importance of cultural conventions motivating users, such as enhancing one's autarky in light of a energy crisis, a fascination for this technological innovation or improving one's 'energy literacy' through learning-by-using. Notwithstanding, when it comes to policy changes, my interview partners highlight the importance of an appropriate pace of change, as too radical interventions into people's private lives might lead to decreasing legitimacy of innovations and social backlash. Hence, this interaction of policymaking and consumers' attitudes calls for future research, especially regarding end-consumer markets and behaviour changes. Drawing on insights from legitimacy and acceptance research (Markard et al. 2016b; Upham et al. 2015; Suchmann 1995), questions to be addressed concern aspects influencing the legitimacy of policy changes and the impact of different narratives as well as arguments in triggering behaviour changes.

Second, the challenge of *justice* plays a key role in particular regarding regulation, since most regulation aims at correcting market failures, optimising social welfare, containing externalities, or reducing transaction costs (Braunerhjelm et al. 2023; Blind 2023). Some regulators I have been interviewing had a rather critical attitude towards residential storage systems, since exemptions from fees and charges for owners of residential storage systems might lead to a higher burden for other users. However, this role of 'warner' and 'mitigator', in turn, has changed the regulators' attitude in light of the growing need to mitigate the midday peak of

photovoltaics, which can be achieved by residential storage systems (Article III). This shows how regulators need to negotiate justice-related aspects, such as the burden with taxes and levies or the affordability for low-income and disadvantaged households, in the context of a pressing demand for new technologies. The debates on energy justice (e.g., Jenkins et al. 2018) or just transitions (e.g., Abram et al. 2022; Swilling & Annecke 2012) provide helpful analytical concepts for scrutinising such trade-offs and their consequences.

8.2.2 Multi-system interactions

As shown in Article I and III, *multi-system interactions* constitute a further challenge in the acceleration phase and at the same time a vivid debate in transitions research (e.g., Löhr & Chlebna 2023; Rosenbloom 2019; Konrad et al. 2008). Referring to Andersen & Geels (2023), I emphasise research that goes beyond a focal system and its interactions with other systems and instead investigates simultaneous changes in various systems. As indicated by my empirical material, designing and implementing smart electricity grids represents such a multi-system challenge involving various systems (electricity, mobility, heat, construction) and crosscutting sectors, such as ICT. Research questions may revolve around complementary technical couplings (e.g., grid flexibility services provided by batteries in electric vehicles), social resistance to the digitalisation and upgrading of grids (e.g., due to concerns regarding data security) or institutional misalignments (e.g., regulation on bidirectional charging, public procurement procedures).

Besides, the findings of this case study encourage research on heat pumps. In addition to storage systems and electric vehicles, heat pumps are a further basic element of residential energy management systems that control the feeding-in and withdrawal of electricity by households according to grid signals. Figgener et al. (2020; 2021) point to an increasing share of new installations of residential storage systems that operate in combination with a heat pump. Notwithstanding, the topic is being discussed highly controversially in Germany with sales numbers of heat pumps lagging behind political targets. Against this backdrop, a comparative design focusing, for instance, on Germany and countries with higher implementation rates (e.g., Sweden or Norway; European Heat Pump Association 2024) bears potential. Taking context-specific factors, such as the electricity/gas price ratio, the availability of flexible electricity tariffs and smart-meters, and the affordability for low-income households, into account provides a valuable analytical lens for addressing questions regarding institutional couplings (Article I) or the above-mentioned social resistance.

8.2.3 Circular economies and regulation

Article III has revealed the need to clarify the conceptualisation of regulation that facilitates or impedes transitions. While this paper is concerned with regulatory implications of challenges unique to the acceleration phase of transitions, there is, to the best of my knowledge, a gap in the literature with regards to the role of regulation in emerging markets. In this context, recent contributions have investigated regulatory experiments (experimenting with new regulation in a real-world-setting; Bauknecht & Kubezcko 2024; Feser et al. 2024). However, these studies neither differentiate between different public policy instruments nor focus on the regulation itself but on the transferability, scalability, and unintended consequences of the experiments.

Based on my empirical material, I suggest looking into the regulatory context of second-life batteries, i.e. batteries that were previously installed in electric cars, buses or trucks and are

later used for other purposes, such as providing grid flexibility services. This case constitutes an emerging market that further allows for bridging the debates on regulation and circular economies. Although there has been a longstanding debate on circular economies (referring to, roughly speaking, reduction/reuse/recycling activities), their translation into binding regulation has been very limited (Peiró et al. 2020). Given the increasing EU endeavours fostering circularity like the *EU Circular Economy Action Plan* of 2020 (European Commission 2025; Peiró et al. 2020), the analytical framework of circular economies provides the opportunity to address the co-evolution of regulation and technological change in different phases including in emerging markets.

Currently, numerous pilot projects deploy second-life batteries for balancing fluctuations in grid voltage by providing flexibility services, for storing electricity as a buffer at fast charging stations or for enhancing the share of self-produced and -consumed electricity (e.g., *Vattenfall* and *BMW*, *MAN* and the University of Kassel, *Sandvik AB* and *ECO STOR AS*). However, the regulatory environment for a mass market still needs to be developed and enacted. For instance, warranty terms of batteries need to be clarified. In this context, a so-called State of Health certification might be necessary, which in turn requires rapid aging tests with standardised indicators (Heininger & Zank 2023). Hence, there is a considerable potential in shedding light on the agency of different stakeholders involved in corresponding pilot projects (Löhr & Chlebna 2023), who (collaboratively) voice their interests aiming at inducing regulatory changes. At the same time, scrutinising capacities and measures of governing entities for drafting and implementing regulation holds potential. Furthermore, we might observe conflicts of use, with second-life usage of old batteries rivalling recycling for obtaining resources. In this context, EU legislation, such as mandatory recycling quotas, constitutes a potential obstacle to second-life business models (Heininger & Zank 2023). Furthermore, recycling used batteries for the sake of keeping resources in Europe can be investigated applying the lens of technology security (Edler et al. 2023).

8.3 Concluding remarks

Siggelkow (2007, 23) concludes his article *Persuasion with Case Studies* with the following thought: *"A paper should allow a reader to see the world, and not just the literature, in a new way. […] If theory talks only to theory, the collective research exercise runs the danger of becoming entirely self-referential and out-of-touch with reality, of coming to be considered irrelevant. […] I am all for theory development; yet theory as a purely self-referential exercise? - rather than as an attempt to better understand the world - strikes me in the end as a poor allocation of time and effort."* When beginning to engage with the field of sustainability transitions, I have particularly been attracted by the first part of this conceptual term: *sustainability*. I have been tempted by the idea of conducting interesting research in terms of current debates, theory development and exchange with colleagues, while at the same time contributing to solving topical, real-world problems, as emphasised by Siggelkow.

Yet, I have come to the conclusion that the latter part – *transitions* – is easier to deal with than the notion of *sustainability*, as the issue of sustainability is incredibly hard to assess, both considering scientific debates and in terms of what actually constitutes a beneficial technology for solving real-world sustainability challenges. I have hardly come across recent discussions of the ambiguity and contested understanding of the concept of sustainability in the scientific debate on sustainability transitions (Fünfschilling 2019 constitutes an exception). Concerning my

empirics, the ambiguity of sustainability is striking, as opinions on residential storage systems from different sustainability perspectives vary widely. While some emphasise their potential in terms of integrating PV and curbing grid expansion, others warn of unfair resource extraction in the Global South, their low efficiency or the needed recycling of used storages. The contribution of social science is arguably to compare and validate these arguments with a critical eye on who is expressing which argument.

As we observe a market-driven, far advanced ramp-up of residential storage systems (BMWK 2023; 2024), for policymakers a focus on the second part – *transitions* – seems pertinent. Given an increasing number of installed systems, policymakers must ensure that the long-begun transition warrants benefits on both the individual and the systemic level, in other words individual expenses and grid reliefs, despite critical voices highlighting the above-mentioned unsustainable aspects of the technology. Notwithstanding, triggered by different developments, such as a change of government or increasingly urgent grid bottlenecks, industry actors, but especially regulatory bodies, have become ever more convinced of the necessity of this transition over the course of this project. Observing and investigating this transition from an institutional perspective, while trying to maintain a neutral stance towards it, not least in light of the key concept of sustainability, has been an intriguing and challenging PhD journey.

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Appendices

Appendix A: List of project outputs

In addition to the three articles and this thesis, the following outputs resulted from my research.

Publications

Zademach H-M, Käsbohrer A (2022) Institutionelle Dynamiken und (ungenutzte) Potenziale im Markt für Heimstromspeicher in Deutschland. *Standort* 46, 279–285.

Käsbohrer A, Zademach H-M (2021) Speichertechnologien und Solarstromspeicher in Deutschland: Grundsätzliche Bedeutung, jüngere Entwicklungen und aktuelle Herausforderungen. In: Becker S, Klagge B, Naumann M (Eds) *Energiegeographie: Konzepte & Herausforderungen*. Stuttgart, Verlag Eugen Ulmer, 182–194.

Zademach H-M, Käsbohrer A (2019) Der Markt für Stromspeicher in Deutschland. *Geographische Rundschau* 71(10), 34–37.

Presentations at conferences and workshops

June 2024	The rescaling of institutional rationalities for shaping opportunity spaces: Lessons from the electricity market in Germany *10th Nordic Geographers Meeting (Copenhagen, Denmark)*
May 2023	Institutional work in multi-system sustainability transitions: Actor interactions at the interface of energy storage systems and electric vehicles in Germany *Workshop on exploring multi-system phenomena in net-zero transitions, University of Oslo (Oslo, Norway)*
August 2022	Organizational and technological innovations in the market for home energy storage systems in Germany: Sustainability transitions at the intersection of energy supply and mobility *NORSI PhD School on Innovation and Sustainability Transitions, Western Norway University of Applied Sciences (Bergen, Norway)*
July 2022	Sustainability Transitions in ko-evolutionärer Perspektive: Jüngere Entwicklungen und Herausforderungen im Markt für Heimspeicher in Deutschland (Sustainability transitions in a co-evolutionary perspective: Recent developments and challenges in the market for residential storage systems in Germany) *KU.Sustainability Research Lab Colloquium (Eichstätt, Germany)*
October 2021	Sustainability transitions at the intersection of energy supply and mobility: New business models and industry dynamics in Germany *International Sustainability Transitions Conference 2021 (online)*
October 2021	Ein Leasingwagen vom Energieversorger und Strom vom Automobilhersteller – Sustainability Transitions an der Schnittstelle von Energie und Mobilität (A leased car from the energy supplier and electricity from the car manufacturer – Sustainability transitions at the interface of energy and mobility)

	German Congress for Geography, #GeoWoche2021 (online)
August 2021	Sustainability transitions and the (unexploited) potentials in the market for energy storage systems in Germany: New entrants and institutional dynamics *RGS-IBG Annual International Conference 2021 (online)*
November 2020	Zum Zusammenspiel von technischen Innovationen und neuen Geschäftsmodellen im Markt für Stromspeicher in Deutschland: Betrachtungen aus der Perspektive der Geography of Sustainability Transitions (On the Interaction of technical innovations and new business models in the market for residential storage systems in Germany: Considerations from the perspective of the geography of sustainability transitions) *AK Industriegeographie (online)*
September 2019	Sustainability Transitions in ko-evolutionärer Perspektive: Das Beispiel organisatorischer und technologischer Neuerungen im Markt für Stromspeicher (Sustainability transitions in a co-evolutionary perspective: The example of organizational and technological Innovations in the market for residential storage systems) *German Congress for Geography (Kiel, Germany)*

Appendix B: Interview guide examples

Note: I have translated the following interview guide examples I, II and VI from German to English. The interview guides were developed before conducting the interviews. Usually, the interviews were conversational, i.e. the guides did not serve as strict manuals, but rather as rough guides.

Interview guide example I (Scoping interview)

The interview took place in March 2021. I talked to a representative of a storage systems manufacturer.

1 Introduction and formalities

- Name
- PhD project at the Catholic University of Eichstätt-Ingolstadt
- Overview over main research questions and the reasons for choosing this market
- Reasons for choosing the interviewee
- Recording and transcription of the interview
- Anonymity, usage of generic identifiers (e.g., industry association representative), usage of direct quotations, possibility for interviewees to check the manuscript before publication

- Interviewee's position, main tasks, CV (professional career leading to the current position)

2 Innovation types

- Which topics or elements of the [company's business model] are currently being worked on?
    - [Different elements of the business model]

- How do the technical and organisational aspects interrelate?
    - Is technology the driving force behind new business models, or the organisational side?
    - Which side is driven more by newcomers and which by established companies?

- On which side are the bigger problems currently?
    - Volumes
    - Regulation
    - [Element of the business model]

- Which side needs greater cooperation and knowledge exchange?
    - Whom does your company cooperate with?
        - Installation partners
        - Manufacturers of communication interfaces, smart meters
        - IT
    - Where does telecommunications expertise come from?
    - How do you develop [Element of the business model] and [Element of the business model]?

- How will this innovative development continue? Where do you see potential for future developments?
    - Materials
    - Reducing resource consumption
    - [Further elements of business models]

3 Regulation

- What is your view of the German regulatory framework when it comes to the implementation of the [company's business model]?
        - Prequalification for [element of the business model]
        - Time pressure in the context of position papers
        - Complexity of regulation
    - Where do injustices / power imbalances exist?
    - How are the conditions established?
        - Who is involved?
        - Which arguments are brought forward?

- What strategies do you use to assert your regulatory interests?
    - How do you cooperate with other stakeholders? With whom?
        - Industry associations
        - Consultancies
        - Informal exchange
    - What arguments do you put forward?
    - Do the automotive and energy industries differ in terms of strategies and interests?

- Which industry has better resources, networks, discourses?

- Can key success factors and obstacles regarding the design of the electricity market and regulation be outlined in a comparison between the different national contexts?
    - Which role do developments in the market for frequency containment response play?
    - What about market regulation?
    - Regulatory barriers?
    - The possibility for further grid services?

- How do you see the role of the EU, i.e. the RED II or the Electricity Market Directive?
    - What about a thorough implementation of EU legislation in Germany?
    - Which consequences do you see?
        - Concerning the missing definition of electricity storage?
        - Regarding fees and taxes?
        - With regard to multi-use?

4 Sector coupling

- To what extent do developments in other sectors induce technical or organisational innovations in the battery storage market?
    - Could this lead to new business models?
        - Cooperation
        - Demand for complete solutions

- How do you assess the opportunities for players from other sectors to enter the battery storage market?
    - Car manufacturers in the role of energy suppliers? Storage manufacturers in the role of e-car leasing contract provider?
    - Synergies or competition?
        - What about the field of heating?
        - Telecommunications?

- How do you assess the possibilities for changing the regulatory framework in light of sector coupling?
    - Do the various actors from the different sectors cooperate, e.g. in industry associations?

- Do you see companies from other sectors investing in the storage industry?

5 Mergers & Acquisitions

- What other benefits did you gain from the [company name] acquisition besides the cash flow?
        - Knowledge exchange?
        - Contact brokering?
    - What knowledge exchange took place?
        - Regarding technology, business models, or regulation?

        - In which direction?
        - With other portfolio companies, e.g. [company name] or [company name]?
    - What do you see as the motivation for [company name]?

- Is this transferable to your other shareholders, [company name] (venture capital) or [company name]?
    - Were your other shareholders interested in knowledge exchange?
    - Has there been contact brokering or coaching?

- At the project level: What does a typical project-financing look like? (Especially for larger projects or industrial loads?)
    - In how far is the battery storage market confusing for investors?
    - People talk about bankability or the emergence of an asset class. How do you see future developments?

- What are the most difficult risks in the industry?
        - Technology
        - Regulation
    - Do you see a connection between investment security and regulation?
        - What will risk assessment be like in the future?

5 Ending the interview

- What do you think am I missing? Should different questions be asked?
- Whom else should I interview?
- Interest in publications.

Interview guide example II (Article I)

The interview took place in September 2022. I talked to an industry association representative in the field of mobility.

1 Introduction and formalities

- Name
- PhD project at the Catholic University of Eichstätt-Ingolstadt
- Overview over research process, main research questions and the reasons for choosing this market
- Reasons for choosing the interviewee
- Recording and transcription of the interview
- Anonymity, usage of generic identifiers (e.g., industry association representative), usage of direct quotations, possibility for interviewees to check the manuscript before publication

- Interviewee's position, main tasks, CV (professional career leading to the current position)

2 Interface of electricity and mobility

- How do you assess the current state of affairs at the interface of mobility and energy?
    - How do you view the business models of automobile companies?
        - Do these only cover charging or also electricity contracts?
    - What about the electricity side?
        - In how far do storage manufacturers offer leasing contracts for electric vehicles?

- What is your view on current developments in the regulatory framework?
    - How do you assess the ENWG and EEG 2021 and the draft amendment for the EEG 2023 with regard to issues at the interface with e-mobility?
        - Such as the expansion of the charging infrastructure (§ 7c Abs. 2 EnWG-E)
        - Regarding bidirectional charging
        - Concerning controllable low-voltage consumption devices (14a EnWG)
        - Charging contracts (processes, responsible)
    - Do you aim at inducing institutional changes?

3 Institutional work

- In your opinion, who are currently the most influential actors and associated positions within the debate on the regulatory framework at the interface of mobility and energy?
    - Regarding the controllable low-voltage consumption devices (14a EnWG), we have observed that the automotive sector succeeded in stopping the law after two years of preparation time. Was this a one-time thing or do we see this more often?
    - What are your strategies?

- What strategies do players in your industry use to assert their regulatory interests?
    - How do they collaborate with other actors?
        - With whom?
        - In the electricity sector?
    - What arguments do you put forward?
    - Automobile companies maintain memberships in energy associations. Are there also increasingly active members of the energy industry in your association?
    - What are differences between the automotive and electricity system?
        - Regarding strategies and interests?
        - Regarding contact persons?
    - Do you try to find communication channels?

- Who (energy or automobile industry) can draw on better conditions? (networks, discourses, resources)
    - Which industry has better access to decision-makers?
        - Do car manufacturers have access to BNetzA and other organisations in the energy sector?

        - Do actors of the energy sector have access, for example, to the Ministry of Transport?
        - Is the charging infrastructure brought forward as an argument towards decision-makers?
    - Which industry has better competences?
        - Is the expertise already there or necessary?
        - Is it easy to obtain expertise in electricity provision?
        - Is there an exchange of employees? (Are employees who previously worked in the energy sector and dealt with regulatory and association issues now in the automotive sector?)
    - What about the built charging infrastructure? Which industry is ahead?
        - What about smaller electricity providers?
    - What about financial resources?
    - Who has the better position to shape the media discourse?
        - Actors of the automobile industry are very active in promoting bidirectional charging. Do customers trust automobile companies to address electricity issues?
    - Which industry is better embedded in social networks?
        - In terms of customer contact
        - Regarding intermediate goods
        - With respect to the retailer network
        - In terms of contact with other actors more generally

- Are business models also deliberately designed for navigating around regulatory obstacles without having to change them?
    - Do you know examples?

4 Multiscalarity

- How do you assess the role of the EU for German regulation?
    - Regarding residential storage systems, conformity between German and EU legislation is claimed for. Does the same apply to e-mobility?
- To what extent do strategies and practices of regulatory work at the EU level differ from those within Germany?
    - Are different resources, media discourses or networks important at different scales?

5 Ending the interview

- What do you think am I missing? Should different questions be asked?
- Whom else should I interview?
- Interest in publications.

Interview guide example III (Article II)

The interview took place in June 2023. I talked to an NGO representative working at the EU level.

1 Introduction and formalities

- Name
- PhD project at the Catholic University of Eichstätt-Ingolstadt
- Overview over research process, main research questions and the reasons for choosing this market
- Reasons for choosing the interviewee
- Recording and transcription of the interview
- Anonymity, usage of generic identifiers (e.g., industry association representative), usage of direct quotations, possibility for interviewees to check the manuscript before publication

- Interviewee's position, main tasks, CV (professional career leading to the current position)

2 Institutional work

- What does your institutional work look like, i.e. how do you elaborate on your arguments, strategies and practices in order to act upon the interests of your members and adapt the regulatory conditions to their needs?
    - Regarding legislative amendments?
    - Trilogue?
    - Regarding the Commission, Parliament, Council?
  - Is there cooperation with other actors?
  - With whom are you exchanging information and ideas in this regard?
    - NGOs?
    - Industry associations at a national or EU level?
    - Energy suppliers?
    - Storage and automobile manufacturers?

- How do you assess the impact of your regulatory work?
  - Are there examples of successful instances or of still existing regulatory barriers?
  - Why?

- Which factors do you regard as being important to a successful institutional work?
  - Central network positions?
  - The public perception/discourses about residential storage systems and e-mobility?
    - Do the arguments at EU level differ from the national scale?
  - Financial resources?
  - Material resources?
  - Access to decision-making

        - What are important institutions/authorities/people?
        - Different from a national scale?
    - Expertise in the field of energy / storaging?
        - Is there a different way of educating at EU level than at the national scale?

3 EU level

- Especially national interview partners point to an enthusiasm about residential storage systems at an EU level. Why is there this enthusiasm?

- In how far are storage systems on the agenda at the EU level?

- How does a topic become centre stage at EU level?
    - How is it possible to translate a national interest to the EU level?
    - Are there differences to the national scale?
    - In your opinion, who are currently the most influential German actors and associated positions within the debate on the regulatory framework at EU level?
    - Is there a unified voice coming from Germany?
- Which arguments are brought forward as well as which strategies and practices are applied by other actors in the context of their regulatory work?

- Can general statements be made about useful factors for a successful regulatory work?
    - Central network positions?
    - The public perception about residential storage systems and e-mobility?

- Is your scope of action for lobbying at an EU level influenced by national dynamics?
        - E.g., Regulation?

4 German level

- Do you try to lobby the national level?
    - Why? Why not?

- How do you assess the role of EU legislation for German regulation in the field of self-consumption by means of residential storage systems and e-mobility services?
    - What are the most important actors?

- Are German industry players adequately aware of the importance of EU regulation
    - In terms of infringement procedures and its consequences?

- How do you assess your scope of impact at a national level?
    - Do EU actors correctly assess the scope of impact possible at a national level?
    - Is the scope of action in Germany influenced by the EU?

5 Ending the interview

- What do you think am I missing? Should different questions be asked?

- Whom else should I interview?
- Interest in publications.

Interview guide example IV (Article III)

The interview took place in June 2024. I talked to a representative of the BMWK.

1 Introduction and formalities

- Name
- PhD project at the Catholic University of Eichstätt-Ingolstadt
- Overview over research process, main research questions and the reasons for choosing this market
- Reasons for choosing the interviewee
- Recording and transcription of the interview
- Anonymity, usage of generic identifiers (e.g., industry association representative), usage of direct quotations, possibility for interviewees to check the manuscript before publication

- Interviewee's position, main tasks, CV (professional career leading to the current position)

2 Roles, resources, skills

- How do you assess the significance of the latest amendments to the EEG and EnWG for the battery storage market?
    - Still a barrier? Rather a driving force for energy storage?
    - Which one, EEG or EnWG, do you consider more relevant for the market for residential storage systems?

- What has been your role during the last amendments?
    - Your personal role?
    - Role of your organisation? Section?
        - Moderator (actors, access)
        - Enabler, promoter (regulation, technology)
        - Giving direction
        - Watch dog, observer, warner
        - Promoter
    - Do you feel enabled to induce regulatory changes?
    - Do you think you have a steering effect? In terms of a strategic direction regarding technology?
    - Are you more concerned with promoting new technologies/strategies or with phasing out old ones?
    - Are you also concerned with infrastructure? Internal structures?

- Do you notice different challenges or "catalysts" in the latest amendments than in previous ones?
    - Which ones and why?
        - Complexity of regulation
        - Insecurity

        - Infrastructure
        - Political conflicts with incumbents regarding phase-outs
        - Justice related issues
        - International developments (value chains, competition)
        - Internal processes
        - New government
        - Political will
    - Are the changes more on the market side or on the authorities/government side?

- How do you assess the increasing merging of energy and mobility in the context of regulation?
    - What challenges or accelerations result from this?
        - New internal processes
        - New actors
        - New market related knowledge
        - Complexity regarding regulation / business models / technologies
        - Conflicts of interests between different systems / political conflicts
        - Insecurity
        - User behaviour
    - New tasks?
        - Coordination / communication

- How do you cope with difficulties and challenges?
    - How did you solve these?
    - Which internal and external factors/resources/competences did help you?
    - Which internal and external factors/resources/competences do you consider necessary, but were lacking?
        - Human resources
        - Knowledge
        - Mandate resources
        - Networks
        - Financial resources
        - Legitimacy
        - Cultural resources
        - Physical resources
        - Analytical skills (regarding markets, business models, regulation, technology)
        - Coordination skills (internal, horizontal with multiple stakeholders, vertical)
        - Operational skills
        - Learning skills
    - Whom do you share ideas with? Advice?

- Did you have any limitations/requirements? By whom? Do you need to prioritise?
- Different from the previous "corporate culture"?
- What new kind of knowledge do you need? Where from?
- Are you aware of consequences of regulation in the market for residential storage systems?
- Do you conduct evaluations?
- How do you respond to criticism from the industry?
- Has cooperation between the ministries changed?
- Have the short deadlines (or simultaneity) for interdepartmental coordination and association consultations improved?
- Are there unclear responsibilities?
- What about your work load?

3 Political skills

- Who do you think are the winners/losers of the amendments?
    - Electricity – Automotive?
    - Incumbents?
  - How do you deal with losers? Compensation?
  - Do you consider the amendments a successful compromise?
  - Where were compromises made?

- How do you assess the interests of the various actors?
  - Which role do these interests play for your work?
    - Moderating
    - Consultations
    - Lobbying
  - Are there conflicts your organisation has to moderate? How?
  - What must be taken into account when communicating with different stakeholders?
  - Do you exert any steering influence? Are you trying to persuade stakeholders to your opinion? Certain groups of stakeholders? The public?
  - In this context, how do you assess the legitimacy / reputation of your organisation?
  - Do certain stakeholders have better or worse access to you/your organisation? Do they have significant influence?
  - Are there established processes for this? Changes?

- The government emphasises technology neutrality. How do you assess technology neutrality in your organisation?
  - How satisfied are you/your organisation with the changes?
  - What is your opinion on storage?

- How do you deal internally with different opinions on residential storage systems?
  - Who can assert their opinion and why?

- Have new processes or governance structures been established?
    - Does knowledge of processes in other departments/ministries need to be acquired?
    - New partnerships? How about the exchange?
        - Electricity – automotive

- How do you assess the political will regarding residential storage systems?
    - Are there changes due to the introduction of the new government or due to market dynamics?

5 Ending the interview

- What do you think am I missing? Should different questions be asked?
- Whom else should I interview?
- Interest in publications.

Appendix C (Article I): Institutional work types and enabling conditions

Table 17: Definitions of forms of institutional work and constituent elements required for different forms of institutional work (R = resources; D = discourses; N = networks).

Institutional work	Definition	Constituent elements
Creating institutions		
Advocacy	The mobilization of political and regulatory support through direct and deliberate techniques of social suasion	R, D, N
Defining	The construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies	R, D, N
Vesting	The creation of rule structures that confer property rights	R, D, N
Constructing identities	Defining the relationship between an actor and the field in which that actor operates	D, N
Changing normative associations	Remaking the connections between sets of practices and the moral and cultural foundations for those practices	D
Constructing normative networks	Constructing of inter-organizational connections through which practices become normatively sanctioned and which form the relevant peer-group with respect to compliance, monitoring and evaluation	R, D, N
Mimicry	Associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption	R, D
Theorizing	The development and specification of abstract categories and the elaboration of chains of cause and effect	D
Educating	The education of actors in skills and knowledge necessary to support the new institution	R, D
Maintaining institutions		
Enabling work	The creation of rules that facilitate, supplement and support institutions, such as the creation of authorizing agents or diverting resources	R, D, N
Policing	Ensuring compliance through enforcement, auditing and monitoring	R
Deterring	Establishing coercive barriers to institutional change	R
Valorizing and demonizing	Providing for public discourse positive and negative examples that illustrate the normative foundations of an institution	D
Mythologizing	Preserving the normative underpinnings of an institution by creating and sustaining myths regarding its history	D
Embedding and routinizing	Actively infusing the normative foundations of an institution into the participants' day to day routines and organizational practices	D, N
Disrupting institutions		
Disconnecting sanctions	Working through state apparatus to disconnect rewards and sanctions from some sets of practices, technologies or rules	R, D, N
Disassociating moral foundations	Disassociating the practices, technologies or rules from its moral foundation within a specific cultural context	D
Undermining assumptions and beliefs	Decreasing the perception of risks of innovation by undermining core assumptions and beliefs	R, D

Source: Lawrence and Suddaby (2006); Duygan et al. (2019; 2021b).

Appendix D (Article I): Overview of participant observation

Table 18: Overview of working group meetings of an industry association for storage technologies, participant observation.

No.	Topic	Date
1	Energy law (working group)	Sep 2020
2	Energy politics (working group)	Sep 2020
3	Task force for EEG amendment	Sep 2020
4	Energy politics working group (presentation by member of EU parliament)	Sep 2020
5	Residential storage systems (working group)	Oct 2020
6	Finance and Investments (working group)	Oct 2020
7	Workshop on residential storage systems	Nov 2020
8	Storage technologies (working group)	Nov 2020
9	Standards and quality criteria (working group)	Nov 2020
10	Trade fair about battery storage systems	Nov 2020
11	Energy law (working group)	Dec 2020
12	Residential storage systems (working group)	Dec 2020
13	Task Force for EnWG amendment	Jan 2021
14	Energy law (working group)	Feb 2021
15	Residential storage systems (working group)	Feb 2021
16	Trade fair on residential and industry storage systems	Mar 2021
17	International market developments (working group)	Mar 2021
18	Energy law (working group)	Apr 2021
19	Energy politics (working group)	Apr 2021
20	International market development (working group)	Apr 2021
21	Workshop on storage systems and manufacturing industry	Apr 2021
22	Storage technologies (working group)	May 2021
23	Energy law (working group)	May 2021
24	Residential storage systems (working group)	Jun 2021
25	Task force Smart Meter Gateway	Jul 2021
26	Energy politics (working group)	Sep 2021
27	Energy law (working group)	Oct 2021
28	Energy law (working group)	Nov 2021
29	Storage technologies (working group)	Feb 2022
30	Energy law (working group)	Feb 2022
31	Energy law (working group)	Apr 2022
32	Residential storage systems (working group)	May 2022
33	Workshop on regulation of fast charging	Jun 2022
34	Energy law (working group)	Sep 2022
35	Storage technologies (working group)	Sep 2022
36	Residential storage systems (working group)	Sep 2022
37	Mobility (working group)	Sep 2022
38	Task force on §14a EnWG	Oct 2022
39	Energy law (working group)	Nov 2022
40	Task force residential storage systems	Jan 2023
41	Residential storage systems (working group)	Feb 2023
42	Mobility (working group)	Feb 2023

Source: Author's elaboration

Appendix E (Article I): Overview of interviews

Table 19: Overview of interviews.

No.	Interviewee	Date
1	Industry association representative (electricity system)	Feb 2021
2	Company for energy management systems, telecommunications: CSO, Consultant	Feb 2021
3	Chamber of Commerce and Industry representative	Feb 2021
4	Private research institute representative	Feb 2021
5	Company for energy management systems, storage systems: Head of business development	Mar 2021
6	Private research institute: Executive director	Mar 2021
7	Storage manufacturer representative: In-house lawyer	Mar 2021
8	Electric utility representative: Product manager	April 2021
9	Chancery for energy law: Lawyer	May 2021
10	Electric utility representative	May 2021
11	Electric utility representative: In-house lawyer	May 2021
12	Chancery for energy law: lawyer	May 2021
13	DSO representative	May 2021
14	Federal Network Agency representative	Jun 2021
15	Industry association representative (electrical industry)	Jun 2021
16	Industry association representative (electrical industry)	Jun 2021
17	State Network Agency representative	Jul 2021
18	Researcher (E-mobility)	Jul 2021
19	Municipal DSO representative	Jul 2021
20	Ministry for Economic Affairs and Climate Action; Civil servant	Jul 2021
21	State Network Agency representative	Jul 2021
22	Transmission System Operator representative	Sept 2021
23	Researcher (electricity system)	May 2022
24	Storage manufacturer representative: In-house lawyer	Juli 2022
25	electric utility: In-house lawyer	Juli 2022
26	Industry association executive director (E-mobility)	Sept 2022
27	Industry association executive director (electricity system)	Sept 2022
28	Industry association representative (automotive industry)	Sept 2022
29	Automotive supplier representative	Jan 2023
30	Storage manufacturer representative: expert for e-mobility and energy management systems	Mar 2023
31	Storage manufacturer representative: CEO	April 2023
32	Industry association representative (electricity system)	Jun 2023

Source: Author's elaboration

Appendix F (Article I): Exemplary empirical material

Table 20: Exemplary empirical material for discourses, resources, social networks and institutional work from interviews.

	Electricity system	Automotive system
Discourses	*"It also has to be said that the market has become so big in the meantime, simply because self-consumption and self-generation include the car and the heat pump. Therefore, the importance of the flexibility markets and the entire grid is falling behind, because you can achieve a lot by saving electricity in the distribution grid." (Interview 31)* *"But he [the customer] buys one [a storage] because he wants it and because he has the money for it and because in his opinion it's great to produce his own electricity, to store his own electricity, to have such a fancy device in the basement and to say: Wow, how self-sufficient I am now. There is a feeling behind it." (Interview 11)* *"If you additionally have an electric vehicle and dimension the storage and the PV system a bit larger, then at some point you will come very, very close to this total self-sufficiency." (Interview 11)* *"Depending on the credibility of the company, they actually buy it that you act in the interests of your customers. Or in the sense of the goals that politics is pursuing anyway and not like: 'well, this is a particular interest.'" (Interview 11)*	*"Even intelligent charging, delaying charging processes, charging while the electricity price is low, when renewables are in the system, of course, that brings incredible flexibility to the system. And at the same time, in our opinion bidirectional charging will actually make a relevant contribution in the near future." (Interview 28)* *"And we [electric utility] look at it [bidirectional charging] a bit differently, because on the one hand we are very surprised, especially when it comes to frequency containment reserve, how much they [automobile companies] see and what they expect from it. That's a pretty good example to show how the automobile industry is advancing into a classic energy topic being extremely present." (Interview 25)*
Social networks	*"But of course, when something comes from a single company, it is always read through the lens of: "Yes, okay, what are the company's interests behind it?" That doesn't mean that you can't have an influence, but associations represent a broader spectrum." (Interview 11)* *"We [DSO] were co-initiators of a large research project, funded by the federal government, working together with other DSOs, with [an electricity provider], [a DSO], [municipal utility], [municipal utility], the entire German automotive industry with the exception of [a car manufacturer]." (Interview 13)* *"There are of course other committees and associations in which the automotive industry is more strongly represented and some of us [transmission grid operators] are certainly also involved. But the main area where we find this are research projects." (Interview 22)* *"The energy department [of BMWK] is dominated by the electric utilities, the grid operators and the municipal utilities, that's it. And someone else doesn't even get in there. It's been going on with us [industry association in the electricity system] for almost 10 years that we don't really get on the energy department and that's why we have to influence the energy department through the economy department." (Interview 27)*	*"Sure, we [association in the electricity system] are also in talks about the different topics with [a car manufacturer], with [an automotive charging subsidiary], with various Japanese and other car manufacturers. They are increasingly turning their backs on their car association, because the car association is a car association and not an energy system association." (Interview 27)* *"Obvious that the automotive industry and the mobility industry are also looking for access to the energy department in the ministry, of course. That was also the problem during the last years, because they didn't actually have this access, because they never had to worry about the issue of electricity, they have always been involved with the economic department in the Ministry for Economic Affairs. That's where they have the influence, that's where they set the agenda, and that's where they made their influence felt regarding § 14a."(Interview 27)* *"Or they [automotive companies] are considering developing a mobility concept, in which many customers are to be supplied with electricity, and they would like to know what to do then. Then we [law firm] advise on charging stations, what kind of tariff is required and how it should be set up." (Interview 9)* *"It is, at least up to now, not necessarily decisive who has the better arguments, but rather who is sitting closer to the BMWK because they write the laws. And so far that has certainly tended to be the electricity industry. But I would assume that something might change in the next few years. We can already see that in the management level of the*

	Electricity system	Automotive system
		BMWK, bidirectional charging actually enjoys a high priority right now and this will of course only be possible with us, the automotive industry." (Interview 28)
Resources	**Authorativ** *"In this respect, the BMWi does not write such regulation on these topics [regarding fees and charges, controllability] without consulting the BNetzA, because the BNetzA has more people and more expertise when it comes to the technical details. As far as the energy department is concerned, the BMWi is extremely thin on staff, i.e. they don't have the people at the moment to be as involved with every topic as the BNetzA. Therefore, the BNetzA is usually consulted. I know many cases where the BNetzA then wrote the relevant paragraph in the EEG, including the justification for the law." (Interview 3)* **Intellectual** *"And we're very relaxed about it. If an automobile manufacturer actually has to earn money through his electricity subsidiary and then has 500,000 customers, then he is on the same level as us. He has to have the same systems, he has to have the same level of professionalism, and then you can see what is actually being earned in the end. Sometimes, that can go really wrong if you're unlucky. That will also clear up a bit again. I'm relatively convinced of that. It's such a hype. The telcos also tried to conquer the electricity market. [Telecom company] and Co. are all gone now because they realized: that's something different. We will see. And those who remain and know their business, that's fine. That's just a new market player or just a new competitor in the game." (Interview 8)* *"Because they [electricity sector] are inherently extremely weak regarding digitalization." (Interview 31)* *"Whereas DSOs have done nothing but prevent standardization for 50 years." (Interview 31)* *"Some of the problems regarding the sector coupling are homegrown, because both major industries, both the automotive and the electricity industries, have been very self-concentrated, and are actually very little open to each other's concerns." (Interview 29)* **Financial** *"We see it now internally in our association work. The little ones [electric utilities] often don't have the resources or the financial means to get involved in lobbying. Some of them don't even have the resources to send representatives to the respective [industry association in the electricity sector] working groups. They depend on an association that solves the problems for them. The larger a company is and the more business models depend on framework conditions, because you don't just want to do standard business, but also want to enter new areas, the more you need suitable framework conditions. And accordingly, you have to provide the necessary resources." (Interview 25)*	**Authorativ** *See electricity system* **Intellectual** *"Yes, there [automotive sector] we [private research agency] are also involved with consulting services. But it's more about the other side. There is no understanding about the electricity side, especially about specific customer groups such as the PV owner." (Interview 6)* *"I do think that our companies [automotive sector] are basically predestined for this [bidirectional charging], simply because we have access to the data, have access to the flexibility and actually also have access to the customer, keyword customer relationship. […] On the other hand, of course, one must also say that these markets require expertise, know-how that has not yet been particularly prevailing in the automotive industry." (Interview 28)* *"The automotive industry is now actually trying to integrate people from other industries." (Interview 29)* *"But whether that makes sense for a company like [a car manufacturer] in the long run, I'm not entirely sure either. Electricity for private customers is a tough mass customer business. That actually only works if you have a very large number of customers and can manage them extremely efficiently." (Interview 13)* *"The car will be well standardized in the future and will not pose an obstacle to the grid because you can reduce it, charge it, charge it smartly, because you can communicate with it, because you can get the information out of the vehicle." (Interview 31)* *"I think it is a big mistake to expect that the automotive industry will adapt the competencies and core competencies of the electricity industry and vice versa. […] It won't work. Individual heads maybe, but not the industry." (Interview 26)* **Financial** *"But you have to be able to afford that there are employees there, both at EU level and at national level, who do more or less nothing else than take care of the regulatory and political framework. Looking at the automotive industry, I can very well imagine that there is a lot of money and a lot of resources there to deal with exactly such topics. Also from a historical perspective, because it's just incredibly important to preserve business models. And now resources are needed to create the framework for the new business models that have become indispensable. But I couldn't say who is more efficient now." (Interview 25)* **Physical-material** *"And that's why the chances of the car are much higher than those of the electricity industry because*

	Electricity system	Automotive system
	Physical-material *"Of course, we [electric utility] see ourselves in a very good position, by offering both private and public charging infrastructure." (Interview 25)* *"Public charging infrastructure is largely a stranded investment. [Electricity provider] has started massively in order to secure this business model and the locations before someone else does it, the good locations. I am very skeptical as to whether this model will work." (Interview 27)* *"What we find time and again in our studies is that the electric utilities are very active in the field of e-mobility - for example, everyone tries to set up charging stations in his own community." (Interview 6)*	*the customer simply thinks of the benefit, and the electricity industry cannot provide them any benefit with a socket. That means they simply don't have the infrastructure you buy, and they're desperately trying to do that with rental models […]." (Interview 31)* *"The electric car is the absolute game changer in the entire energy system. At least for a few years, the e-car will probably become the mobile energy device that we have in our system, towards which everything will ultimately be geared and which will then have a very disruptive effect on the classic energy world. […] Tomorrow, I get my car from [car manufacturer], get the electricity from [car manufacturer], then I can turn the heating up and down via the digital services in my car. So, I will also have the entire energy management via my [car manufacturer]app." (Interview 27)* *"You can see that the business models of the electric utilities are being threatened by people from outside the industry, since [car manufacturer] and [car manufacturer] have their own charging electricity tariffs. And other automakers will follow. So the classic business model of the electric utilities, i.e. the sale of electricity, is taken over by others, which means they have more competition." (Interview 6)* *"The tail is wagging the dog, because the car costs more than the entire PV equipment in the end. You can say, if a customer pays a laid-back 2,000 for aluminum rims, he might conclude an electricity contract that is cheaper than the aluminum rims per year. I can imagine that being a bonus." (Interview 13)* *"And because the electricity industry is taking a frontal stance against the automotive industry, because they will be competitors in the future, because the network is unbundled, and tell me one reason why, if you have advantages buying an ID 3 with a charging station and electricity contract, why shouldn't you do that, […] It just doesn't suit the electricity industry at all that storage systems are getting off the ground on wheels, it doesn't suit them as a load in the distribution grid and there will be eternal quarrels that can't be resolved except through standardization." (Interview 31)*
Institutional work	*"There is a new legislation by the EU commission and we [industry association in the electricity system] are part of the process. […] We maintain contacts with different institutions in legislation, with the Bundestag, the European parliament, EU Commission, different general directorates at EU and national level, different ministries, state ministries and parliaments." (Interview 1)* *„It's the case that many competitors are collaborating within working groups, particularly with respect to regulation, in order to exert influence in this regard. There is little activity regarding business models, little regarding technology, but a lot when it comes to regulation and requirements." (Interview 2)*	*"Of course, some of our member companies do this themselves to a certain extent, but as an association we work on communication in the media, and we also have our own press department, because of course the public mood also has a certain influence on political decision-making processes. That means we communicate with the general public and also with the political arena. This means that we are in regular contact with the federal government, with the individual ministries, and of course especially with the Ministry of Transport. Now more and more with the BMWK, simply because the topics related to grid energy are becoming more and more important for the automotive industry. With the Bundestag [parliament], but then of course also with the federal states." (Interview 28)*

	Electricity system	Automotive system
	"Yes, of course, there are various mostly informal gatherings here in Berlin at the association level on all sorts of topics, you are then in different rounds." (Interview 3)	*"[Automotive charging subsidiary] has also been in the press for months now and is demanding reasonable conditions for bidirectional charging and is also painting an extremely positive picture of what can be done there now in the context of grid stability." (Interview 25)*
	"We [storage system manufacturer] fought with [car manufacturer] to ensure that the charging stations are not curtailed by the smart meter, but can also be curtailed via an energy management system. […] Eventually, one can say that this is lobbying for the manufacturers of energy management systems and components. […] That's what it looks like when two worlds meet, and you have to find a compromise." (Interview 31)	*"I've [storage manufacturer representative] been doing energy transition issues since 2008, 2009, back then it wasn't even an issue. When you saw e-mobiles, they were always recumbent bikes, where some hobbyist screwed his battery into the back. Everyone said why it never worked, wasn't cool. At some point an Elon Musk will come along and just build a cool car and, as you say, create an enthusiasm that can then turn an entire industry upside down." (Interview 7)*
	„So far, however, one has to say that, for the most part, there is still consensus, one does not block each other all the time, there is still agreement on many issues at the moment. For now. Let's see how this develops." (Interview 25)	*"Nevertheless, it is of course the case that the interests are sometimes very different. […] This also showed that the different sectors did not come to a common denominator, so that in the end, of course, the associations also fight for their cause to some extent and ultimately do this in public. […] There are simply different interests involved. And to a certain extent, these can also be resolved professionally, although there are many things we simply don't know yet to that extent." (Interview 28)*
	"Of course, they are putting a bit of pressure on the energy industry. Well, that goes down well with us: 'Oh my God, bidirectional charging seems to be the ultimate now.'" (Interview 25)	

Source: Author's elaboration

Appendix G (Article I): Institutional context and regulatory changes

The institutional context is mainly characterized by two dominant rationalities, a decentral electricity supply and a rather centralized electricity supply. Actors promoting the latter are mainly the Federal Network Agency (Bundesnetzagentur, BNetzA), part of the BMWK (especially until the end of 2021), several (mostly municipal) electric utilities and DSOs as well as the associated industry associations. Regarding the approximately 870 German DSOs, our empirical material indicates great heterogeneity with some stakeholders welcoming private storage systems and even launching research projects, but the large majority being critical towards them.

Their main arguments are, first, the objective of a secure supply. Therefore, predictability and central tractability of electricity loadand generation are deemed indispensable. Electrical load and generation of households using residential storage systems, however, are stated as being difficult to predict and control. Furthermore, residential storage systems are considered rather expensive and resource consuming compared to their applicable capacities. BNetzA representatives question their need and profitability at all and rather plead in favor of a full feed-in of self-produced electricity. They draw on the arguments of following market signals in an efficient way and of a true-cost pricing of net electricity with grid fees, since electricity must be kept available to its full extent at any time in spite of storage systems. In the same vein, many sector experts doubt the benefits of frequency containment reserve and bidirectional charging due to the little demand, low prices, and therefore required customer behavior.

The regulatory framework is regarded by industry experts as being the central obstacle to a more profitable realization of business models involving storage systems and e-mobility services. In Germany, the renewable energy act (Erneuerbare-Energien-Gesetz, EEG) and the energy industry act (Energiewirtschaftsgesetz, EnWG) make up the central regulatory framework for the promotion of renewable energies. To exemplify a regulatory barrier, the term 'energy

storage' has not been defined until 2022. Instead, EEG and EnWG regarded the storing of energy in a storage system as consumption and the extraction of electricity from the storage system as production. Thus, every storage and withdrawal in the course of self-consumption was charged with grid fees, taxes and EEG surcharge (EEG-Umlage). Furthermore, electricity trading as part of energy communities and the storage of grid power for the mentioned frequency containment reserve has gone along with vast complexity since the different electricity flows have been charged with different taxes and fees respectively and, thus, have to be measured separately. Regulation regarding bidirectional charging is missing at all (for a detailed overview including recent amendments see Table 5).

As regards amending the central policies, formal decision-making power over energy policy lies with the German federal parliament. The substantive work on the legislation is mainly the responsibility of the BMWK. However, although being intended as downstream, executive authority, the BNetzA wields considerable power over legislation providing extensive advisory services to the ministry, and even developing draft laws on their own initiative based on a high level of personal commitment.

Our empirical material suggests that the actor configuration in charge of energy regulation is to a large part characterized by a critical attitude towards residential storage systems. While a large majority of parliamentarians is in fact regarded as being rather openminded towards the new business models (especially by industry associations), the BMWK (mainly until 2021) is criticized for consciously deterring private storages systems by means of the aforementioned regulatory barriers in EEG and EnWG. Some interviewees (mostly industry associations) even go as far as saying that certain laws (e.g., regarding charge reliefs) are deliberately made too complex to be applicable or that deadlines for industry associations to hand in positions papers are consciously set tight. Furthermore, German legislation is criticized for navigating around EU legislation, which claims a more storage friendly regulation. Beyond ensuring compliance with the energy acts on the part of DSOs, industry and end consumers, the BNetzA is stated by many interviewees to use its authoritative resources in order to favor the interests of DSOs, e.g. by promoting high charges and fees for selfconsumption and far-reaching control options over storages and electric vehicles for grid operators. The agency communicates its critical attitude towards residential storage systems and its benevolence towards a large-scale market-based electricity trading to political parties, civil servants and the public.

However, there have been changes benefitting a more profitable implementation of new business models. Among others, recent amendments raised the threshold for exemptions from the EEG surcharge from a storage capacity of 10 kWh to 30 kWh and simplified metering by focusing merely on the grid connection point. The legal definition of 'energy storage' was introduced into the EnWG in 2023 and abholished the double charging with fees, taxes and surcharges. Also in 2023, the EEG surcharge was suspended. However, there are challenges remaining, for example, ambiguities concerning grid fees and electricity taxes for multi-use applications (especially energy communities) or permitted grid charging periods for electric vehicles.

Appendix H (Article II): Institutional work types

Table 21: Definitions of forms of institutional work and constituent elements required for different forms of institutional work (R = resources; D = discourses; N = networks).

Institutional work	Definition
Creating institutions	
Advocacy	The mobilisation of political and regulatory support through direct and deliberate techniques of social suasion
Defining	The construction of rule systems that confer status or identity, define boundaries of membership or create status hierarchies
Vesting	The creation of rule structures that confer property rights
Constructing identities	Defining the relationship between an actor and the field in which that actor operates
Changing normative associations	Remaking the connections between sets of practices and the moral and cultural foundations for those practices
Constructing normative networks	Constructing of inter-organisational connections through which practices become normatively sanctioned and which form the relevant peer-group with respect to compliance, monitoring and evaluation
Mimicry	Associating new practices with existing sets of taken-for-granted practices, technologies and rules in order to ease adoption
Theorising	The development and specification of abstract categories and the elaboration of chains of cause and effect
Educating	The education of actors in skills and knowledge necessary to support the new institution
Maintaining institutions	
Enabling work	The creation of rules that facilitate, supplement and support institutions, such as the creation of authorising agents or diverting resources
Policing	Ensuring compliance through enforcement, auditing and monitoring
Deterring	Establishing coercive barriers to institutional change
Valorising and demonising	Providing for public discourse positive and negative examples that illustrate the normative foundations of an institution
Mythologising	Preserving the normative underpinnings of an institution by creating and sustaining myths regarding its history
Embedding and routinising	Actively infusing the normative foundations of an institution into the participants' day to day routines and organisational practices
Disrupting institutions	
Disconnecting sanctions	Working through state apparatus to disconnect rewards and sanctions from some sets of practices, technologies or rules
Disassociating moral foundations	Disassociating the practices, technologies or rules from its moral foundation within a specific cultural context
Undermining assumptions and beliefs	Decreasing the perception of risks of innovation by undermining core assumptions and beliefs

Source: Lawrence and Suddaby (2006).

Appendix I (Article II): Overview of participant observation

Table 22: Overview of working group meetings of industry association, participant observation.

No.	Topic	Date
1	Energy law working group	Sep 2020
2	Energy politics working group	Sep 2020
3	Task force for EEG amendment	Sep 2020
4	Energy politics working group (presentation by member of EU parliament)	Sep 2020
5	Working group on residential storage systems	Oct 2020
6	Finance and Investments working group	Oct 2020
7	Workshop: Residential storage systems	Nov 2020
8	Storage technologies working group	Nov 2020
9	Standards and quality criteria working group	Nov 2020
10	Trade fair about battery storage systems	Nov 2020
11	Energy law working group	Dec 2020
12	Working group on residential storage systems	Dec 2020
13	Task Force for EnWG amendment	Jan 2021
14	Energy law working group	Feb 2021
15	Working group on residential storage systems	Feb 2021
16	Trade fair on residential and industry storage systems	Mar 2021
17	International market developments working group	Mar 2021
18	Energy law working group	Apr 2021
19	Energy politics working group	Apr 2021
20	International market development working group	Apr 2021
21	Workshop: Storage systems and manufacturing industry	Apr 2021
22	Storage technologies working group	May 2021
23	Energy law working group	May 2021
24	Working group on residential storage systems	Jun 2021
25	Task force Smart Meter Gateway	Jul 2021
26	Energy politics working group	Sep 2021
27	Energy law working group	Oct 2021
28	Energy law working group	Nov 2021
29	Storage technologies working group	Feb 2022
30	Energy law working group	Feb 2022
31	Energy law working group	Apr 2022
32	Working group on residential storage systems	May 2022
33	Workshop: Regulation of fast charging	Jun 2022
34	Energy law working group	Sep 2022
35	Storage technologies working group	Sep 2022
36	Working group on residential storage systems	Sep 2022
37	Mobility working group	Sep 2022
38	Task force on §14a EnWG	Oct 2022
39	Energy law working group	Nov 2022
40	Task force residential storage systems	Jan 2023
41	Working group on residential storage systems	Feb 2023
42	Mobility working group	Feb 2023

Source: Author's elaboration.

Appendix J (Article II): Overview of interviews

Table 23: Overview of interviews.

No.	Interviewee	Date
1	Industry association representative (energy sector)	Feb 2021
2	Company for energy management systems, telecommunications: CSO, Consultant	Feb 2021
3	Chamber of Commerce and Industry representative	Feb 2021
4	Private research institute representative	Feb 2021
5	Company for energy management systems, storage systems: Head of business development	Mar 2021
6	Private research institute: Executive director	Mar 2021
7	Storage manufacturer representative: In-house lawyer	Mar 2021
8	Energy utility representative: Product manager	April 2021
9	Chancery for energy law: Lawyer	May 2021
10	Energy utility representative	May 2021
11	Energy utility representative: In-house lawyer	May 2021
12	Chancery for energy law: lawyer	May 2021
13	Distribution grid operator representative	May 2021
14	Federal Network Agency representative	Jun 2021
15	Industry association representative (electrical industry)	Jun 2021
16	Industry association representative (electrical industry)	Jun 2021
17	State Network Agency representative	Jul 2021
18	Researcher (E-mobility)	Jul 2021
19	Municipal grid operator representative	Jul 2021
20	Ministry for Economic Affairs and Climate Action: Civil servant	Jul 2021
21	State Network Agency representative	Jul 2021
22	Transmission grid operator representative	Sept 2021
23	Researcher (energy sector)	May 2022
24	Storage manufacturer representative: In-house lawyer	Jul 2022
25	Energy utility: In-house lawyer	Jul 2022
26	Industry association executive director (E-mobility)	Sept 2022
27	Industry association executive director (energy sector)	Sept 2022
28	Industry association representative (automotive industry)	Sept 2022
29	Automotive supplier representative	Jan 2023
30	Storage manufacturer representative: expert for e-mobility and energy management systems	Mar 2023
31	Storage manufacturer representative: CEO	April 2023
32	Accredited Parliamentary Assistant at European Parliament	April 2023
33	Energy utility: representative at EU level	April 2023
34	EU-level industry association representative (energy sector); former EU-level consultancy representative	April 2023
35	EU-level industry association representative (energy sector)	April 2023
36	EU-level industry association representative (energy sector)	April 2023
37	EU-level industry association representative (energy sector)	April 2023
38	Industry association representative (energy sector)	May 2023
39	EU-level NGO representative (standardisation)	Jun 2023
40	EU-level NGO representative (environment, sustainability)	Jul 2023

No.	Interviewee	Date
41	EU-level consultancy representative	Aug 2023
42	Ministry for Economic Affairs and Climate Action: Civil servant	Nov 2023
43	EU Commission General Directorate	Nov 2023

Source: Author's elaboration.

Appendix K (Article II): Exemplary empirical material

Table 24: Exemplary empirical material for opportunity spaces (4.1), institutional work (4.2) and conditioning factors (4.3) for the national and EU scale from interviews.

	Exemplary quotes
4.1	*"In Germany, 80 or 90 percent of all solar roofs are equipped with storage systems. In other countries, there are much fewer […]. Different factors play a role […], particularly the regulatory context. For example, in Germany there were low feed-in tariffs for a relatively long time." (Interview 36, EU-level industry association)* *"That's why there is considerable disappointment not only in the storage industry, but among many energy innovators about the implementation, where you can clearly see that someone is really just jumping as high as they have to […]. Energy communities are simply not implemented, double burdens [with taxes and charges] are simply ignored. This is a pity. There is a disconnect between those who implement the legal framework and those who technically bring it onto the streets." (Interview 7, German storage manufacturer).* *"Regarding the question whether energy sharing can and should be implemented within Europe, there are big differences. In Germany, this doesn't work at all. But in Portugal and France it already works and is already being done." (Interview 36, EU-level industry association)* *"I believe that the development of residential storages will only go in one direction and that is upwards, I am 100% convinced of that. Batteries are becoming cheaper and the concepts and systems, establishing themselves on the market, are getting better and I believe that this is a very big future segment. Above all, this motivation of the energy transition happening at home is also a very big one. Most home storage owners don't calculate down to the last cent whether it's really worth it. […] They just think it's nice when they fill up their storage with their self-generated electricity or charge their cell phones every day." (Interview 42, German Ministry for Economic Affairs)* *"I think the institutions here [EU] see it as a really viable way to help with the topic of the renewables since you have periods of overproduction that you can save some of the energy that you are not using in the moment and deploy it later. I think that they see overall in the home storage sytems roll-out whether it be through like a battery wall or something that we are promoting quite a bit are batteries on wheels you know through electric vehicles." (Interview 37, EU-level industry association)* *"We think, first of all, the EV is already a form of home storage, so since theses batteries are in use anyway, we think this is, where the first focus should be, to actually make sure that those can be integrated in the building and that solar energy can be stored there." (Interview 39, EU-level NGO)* *"At the moment the narrative is more focused on EVs, to other forms of storage, but their [residential storage systems] argument is there, […] maybe there is a bit too much focus still on centralised systems, so, large storage systems for big renewable generation plants rather than home based solutions." (Interview 41, EU-level consultancy)*
4.2	***Institutional semi-coherence:*** *"We [EU-level industry association] have to compromise quite a bit to reach an inherent position among our members, you know, in Europe, we are representing a 500 utilities it can be difficult sometimes to climb the middle way." (Interview 37, EU-level industry association)* *"EU legislation is too abstract to really include such specific technical solutions, which is a challenge. […] That's why an EU directive on batteries wouldn't work at all, because you would have to intervene too heavily in a country, so there is often no real common denominator when it comes to residential storages." (Interview 36, EU-level industry association)* ***Complex regulation at both scales:*** *„[…] that decisions are made by people who are not actually involved in the national legislative process and that the national legislators are suddenly faced with such a document where they don't actually know exactly what to do with it, what that's all about, and that it simply doesn't fit into the dynamics of national politics." (Interview 36, EU-level industry association)* *"What's coming now with the EU's new electricity market design, you can no longer keep up, it's huge changes, it's become incredibly complicated." (Interview 42, German Ministry for Economic Affairs)*

Exemplary quotes

Lacking knowledge on regulation:

"It's a matter of capacity […] the way things work in Brussels is different compared to the way things work at national level. […] but we don't have the capacity to also have people covering national level." (Interview 34, EU level consultancy)

Expecting reservations:

"[…] kind of a common narrative that we hear between the people who work in the Brussels bubble and those that work on national politics that there is a lot of imposition happening from the EU level." (Interview 37, EU-level industry association)

"Compared to others, we are more strongly engaged in reaching out to ministries in collaboration with national associations […] and that's a challenge, since we are not perceived as a domestic actor […] The people working in these [EU level] lobby associations are sometimes simply too tied to working traditions. That's why they don't do it, they don't really believe in it. […] The EU is definitely perceived as hostile in the ministries." (Interview 36, EU-level industry association)

EU's influence underestimated at a national scale:

"So what you can see is that the influence of EU legislation in Germany is still totally underestimated. Many people don't have this on their radar at all, even though a lot has happened. So European regulations and directives on energy issues have only been in place for a few years." (Interview 12, German lawyer)

"In the role of guardian of the treaties, the EU Commission certainly has a need to sharpen up the matter because it has really brought very little to court in recent years. I admit that the Commission sometimes turns a blind eye and lets it pass." (Interview 33, German corporate representation in Brussels)

Lack of monetary or personal resources:

"The bigger companies have bigger voice, they have membership there, they have an office in Brussels, they know what they are talking about, they have the man power to focus on the issues, small companies maybe don't have the time to focus on european level even though its driving all the changes even on a national level." (Interview 34, EU-level consultancy)

National agents perceiving the EU scale to be relevant:

"In some cases it [EU-legislation] is even more important than national legislation, because regarding many aspects we experience that new regulations that are now coming from the EU have completely reduced current national legislation to absurdity. So it's important to know what's happening at EU level, and we're also trying to incorporate some steering effects here." (Interview 26, German industry association)

"We are a national association in this respect, but we are increasingly and strongly involved in Europe because it is important of Germany. […] to accommodate our companies there as well, the entire regulatory system comes from Brussels, we have to get very involved there." (Interview 27, German industry association)

"Eventually, a very large part of the energy system is predetermined by European guidelines. Sometimes you can only devise things nationally, which is why it is important that the European rules are not only kept in mind, but also to actively contribute to their development." (Interview 38, German industry association)

Expected enthusiasm:

„Particularly at EU level, in all the debates, in all the regulatory processes, including regulations, there is a lot more vision to be seen, of what should be made possible in the future in order to give a new technology scope for action. […] I experience that the dialogue with Brussels is significantly more constructive and significantly more visionary than at the federal level." (Interview 26, German industry association)

Expected transparency:

"So basically you have to say that the European Parliament is very transparent. All documents are published and all amendment requests are accessible. Many committees have an intra-list where you can see exactly which rapporteur is determined and we then know which committee is responsible for the dossier. Then the rapporteur is nominated, the shadow rapporteurs, you can see all of that on the Parliament website. The draft report, you can now also take part electronically. […] In the Council - you are right - it is less transparent." (Interview 33, German corporate representation in Brussels)

Perceived relevance of standardisation:

"The [dynamic] can be explained by the fact that manufacturers are constantly demanding more harmonisation and standardisation. […] That it is implemented at the European level because that would be a huge problem if 27 different solutions were to emerge […] and at that point […] they then decide to have an impact on it at the European level." (Interview 36, EU-level industry association)

National perspective:

"For example, the MEPs actually meet exceptionally often with the companies, some of which even have closer contacts with the MEPs than we. […] Companies have more opportunities, for example, German companies talk to

	Exemplary quotes
	German MEPs.This national orientation plays a role again." (Interview 36, EU-level industry association)
	"So they [national associations] might have easier access to their permanent representatives or to their MEPs than we do. Generally, we invite them to come with us, whenever we are meeting with somebody from their countries. […] It helps us legitimise a little bit more, not just the big guys in the EU in Brussels." (Interview 37, EU-level industry association)
	Germany's size as member state:
	"We are the largest member state, we are the largest payer. And what Germany says obviously has a certain weight in Brussels." (Interview 27, German industry association)
	„Germans are a bit more confident that they can have their way through things anyway, they can sort things out, yes, maybe that's, I don't know, just attitude. I see that they are a bit more confident, but maybe this also comes from the fact that it is quite obvious that Germany and France are the most influential member states." (Interview 34, EU-level industry association)
4.3	***Institutional work activities:***
	"The EU requirements clearly state that storage facilities should not have multiple or double burdens and should not be slowed down by bureaucratic obstacles. This brings us back to a central area that is particularly important to us. With the EU, we have a partner that has passed legislation that provides everything we need to bring storage on a par with energy generation technologies." (Interview 1, German industry association)
	"We have carried out in-depth analyzes of what needs to be implemented in our opinion. […] we also published the distillate as an article in the Journal for New Energy Law. […] For people who are interested in implementation, so that they can search for the European template in the EEG and EnWG." (Interview 7, German storage manufacturer)
	"We need to tailor so much, because there's still big challenges in the context of taxation, of support schemes, of grid fees, grid connections or permitting. So, usually, it's very rare that we do our lobbying activities explicitly for behind-the-meter [applications for end consumers], usually it goes hand in hand with something else." (Interview 35, EU-level industry association)
	"There is usually one large incumbent that they also will have an office here in Brussels and it will be collaboration with the assocation but there are some things where they have to represent their companies. Specific interests that might not align perfectly with the associations." (Interview 37, EU-level industry association)
	„There are industry associations at the European scale, with which we communicate more closely, since we maintain also memberships. […] But usually, we also take part directly in consultations in order to bring in a more national perspective." (Interview 38, German industry association)
	"In Brussels, too, the principal topic is informing, because the top people have to understand it in order to be able to transport it downwards." (Interview 26, German industry association)
	„Of course, creating ideas and visions about storages, particularly large storages, short-term storages, being essentially important for the systems, for providing grid services." (Interview 38, German industry association)
	„Particularly regarding drafting the products concerning frequency containment reserve, which have been modified over years. We have been taking part in every consultation in order to argue that storage systems of all sizes should make a realistic and relevant contribution." (Interview 38, German industry assocation)
	"Eventually, we pursue our interests through the [EU-level] associations and we also pursue our interests individually. […] [Electricity provider] does not always have to agree with us on every detailed regulation. And it is also very difficult for the associations here to respond to particular interests." (Interview 33, German corporate representation in Brussels)
	„They are very aggressive […] in pushing this standard. They are quite good in their PR. They are all over the policy landscape. […] They managed to basically take over a European standardisation group where they pretend to be developing the standard, but actually […] it's behind closed doors with their members." (Interview 39, EU-level NGO)
	Institutional work outcome:
	"The EU is also doing good things, for example the EEG levy on self-consumed electricity. The limit in Germany used to be 10 kW peak. The limit was raised to 30 KW peak thanks to the EU. That wouldn't have happened voluntarily in Germany." (Interview 10, German electricity provider)
	"There was also enormous pressure from various companies in the storage industry and they have now been heard more than before. And of course the template from the EU, which states that double burdens must be avoided. […] And yes, that has now made a hit and the driving forces are clearly the factions in Parliament […]."(Interview 12, German lawyer)

	Exemplary quotes
	"The EU directive prescribes 30 kw. We had to fight hard for the BMWi [today BMWK] to simply implement this requirement one-to-one in the EEG. […] This happened, just because they have realised that there will be endless complaints [by the EU]. […] But not because they are convinced of it." (Interview 11, German electricity provider)
	"[…] regarding the current legal framework, EEG and ENWG. I have to say: what this government [introduced at the end of 2021] has already introduced - in terms of simplifications - we haven't had that in the last 16 years. It's unbelievable how quickly things are suddenly happening and we're actually pretty excited about how this is being discussed at the moment." (Interview 25, German electricity provider)
	"The question is whether it is a good strategy to demand that the EU directives are not implemented. I think, the strategy was bad and is bad […]. You can do that [make use of residential storages], it's just not practical [due to regulatory complexity]. According to energy law it is possible, just not practical." (Interview 38, German industry association)
	"It's clear that the level of presence and interest of companies is really expanding. […] Companies are giving more strategical importance, and […] many CEOs, managing directors, important members of companies, are directly involved, and now directly come to Brussels to events to talk with the commission." (Interview 34, EU-level industry association)
	"To be fair, we still have two files […], the energy efficiency directive and the energy performance of building directive, that are being elaborated but again in those documents energy storage's role is not so big, it's there but we think that could be a bit more, to be honest." (Interview 35, EU-level industra association)
	"The laws that are currently being negotiated […] do not contain any central requirements for residential storages. That means that relatively little actually changes. What happens a bit is that in data traffic specifications, such as how a home storage system can be connected to the DSO, there is just a bit of dynamism coming into the matter, i.e. that more standardisation is being created." (Interview 36, EU-level industry association)

Source: Author's elaboration.

Appendix L (Article II): Role of EU institutions for policymaking

Table 25: The role of EU institutions for policymaking.

Institution	Function in policymaking
European Commission	▪ Main executive body, includes Directorate-Generals (departments with specific zones of responsibility) ▪ **Policy initiating** Enjoys the sole right to initiate and draft legislation In-house knowledge, but also relying upon an extensive advisory system of public and private actors, paid consultants and expert groups (e.g., national government nominees, interest group representatives, trade unions, scientists) for consultation and pre-negotiation ▪ **Decision making** Role of broker and consensus drafter between Council and Parliament (part of conciliation committee mediating between Parliament and Council) ▪ **Implementation** Discretion to interpret legislation and issue administrative regulations or decisions Oversees the implementation of its laws and policies and is charged with ensuring that they are respected (together with the Court of Justice) Often committees (subnational or national officials, interest group representative, technical experts, scientists) assisting the Commission in executive work
European Parliament	▪ Autonomous, directly elected Parliament ▪ **Policy initiating** Enabled to request the Commission to produce proposals

Institution	Function in policymaking
	▪ **Decision making** In ordinary legislative procedures (applies to around 85 policy areas): co-equal right with Council to adopt EU legislation In special legislative procedures: regarding consent procedures (e.g., accession or withdrawal of EU members), right to reject legislation, but not amending it; regarding consultation procedures (e.g., competition law), Parliamentary consultation required for Council to pass legislation Establishing and approving EU budget
Council of the EU / Ministers (CoM) ('the Council')	▪ Represents the governments of EU countries, meeting of national ministers for adopting laws and coordinating policies ▪ **Policy initiating** Enabled to request the Commission to produce proposals ▪ **Decision making** In ordinary legislative procedures (applies to around 85 policy areas): co-equal right with Council to adopt EU legislation In special legislative procedures: regarding consent procedures (e.g., accession or withdrawal of EU members), right to adopt legislative proposals after obtaining the consent of the Parliament; regarding consultation procedures (e.g., competition law), right to adopt a legislative proposal after the Parliament has submitted its opinion on it. However, the Council is not legally obliged to take the Parliament's opinion into account.
European Council (EUCO)	▪ Summit of the heads of state or government of the EU member states (plus the president of the Commission) ▪ **Policy initiating** Enabled to request the Commission to produce proposals Immense prestige and legitimacy, quasi-legal status as body defining rather general political guidelines (e.g., on foreign and security policy) than specific policy proposals

Source: EU (2024a, 2024b); European Commission (2024c); EP (2024); EUCO & CoM (2024); Hooghe & Marks (2001)

Appendix M (Article II): Most relevant EU directives concerned with residential storage systems

Table 26: Most relevant EU directives concerned with residential storage systems.

Act	Overall targets	Most relevant targets regarding residential storage systems
Renewable Energy Directive (Directive 2018/2001)	▪ Development of clean energy across all sectors of the EU economy, supporting cooperation between EU countries towards this goal ▪ Electrification (of cooling, transport, industry, buildings and district heating/cooling), promoting electric vehicles and smart recharging ▪ Overall renewable energy target of at least 42.5% binding at EU level by 2030, but aiming for 45% ▪ Strengthening energy security ▪ Promoting faster and easier permitting procedures for renewables ▪ Allowing citizens to play an active role in the development of renewables by enabling renewable energy communities and self-consumption of renewable energy ▪ Part of Clean energy for all Europeans Package	▪ Rules on self-consumption Art. 21, 1: consumers are entitled to become renewables self-consumers Art. 21, 2: renewables self-consumers, individually or through aggregators, are entitled (a) to generate, consume, store renewable energy and sell their excess production, including through electricity suppliers and peer-to-peer trading arrangements without discriminatory or disproportionate procedures and charges, and to (network) charges,that are not cost-reflective, neither for electricity they consume from or feed into the grid nor for self-generated electricity, (b) to install and operate electricity storage systems combined with installations generating renewables for self-consumption without liability for any double charge, including network charges, for stored electricity remaining with their premises, (c) to maintain their rights and obligations as final consumers, (d) to receive remuneration including support schemes for self-generated renewable electricity they feed into the grid. Art. 21, 3: Member States may apply non-discriminatory and proportionate charges and fees to renewables self-consumers if (a) the self-generated renewable electricity is effectively supported via support schemes, (b) if the total installed electrical capacity of installations is more than 30 kW. Art. 21, 4: Member States shall ensure that renewables self-consumers located in the same building, including multi-apartment blocks, are entitled to engage jointly in activities referred to in paragraph 2 and that they are permitted to arrange sharing of renewable energy that is produced on their site or sites between themselves, without prejudice to the network charges and other relevant charges, fees, levies and taxes applicable to renewables self-consumers. Art. 21, 6: Member States shall put in place an enabling framework to promote and facilitate the development of renewables self-consumption based on an assessment of the existing unjustified barriers to, and of the potential of, renewables self-consumption in their territories and energy networks, including, inter alia, accessibility of renewables self-consumption to all final customers; and addressing unjustified barriers to the financing of projects in the market and measures to facilitate access to finance or unjustified regulatory barriers to renewables self-consumption, including for tenants. ▪ Rules on energy communities Art. 21, 2 (see above), Art. 21, 4 (see above), Art. 21, 6 (see above) Art. 22, 1: final customers, in particular household customers, are entitled to participate in a renewable energy community while maintaining their rights or obligations as final customers, and without being subject to unjustified or discriminatory conditions or procedures preventing their participation in a renewable energy community. Art. 22, 2: renewable energy communities are entitled to produce, consume, store, sell and share renewable energy and to access all suitable energy markets both directly or through aggregation in a non-discriminatory manner.

Act	Overall targets	Most relevant targets regarding residential storage systems
	▪ Adopted in 2009, revised in 2018, 2023	Art. 22, 3: member states shall carry out an assessment of existing barriers and potential of renewable energy communities Art. 22, 4: member states shall provide an enabling framework to promote and facilitate the development of renewable energy communities addressing, inter alia, unjustified regulatory and administrative barriers to renewable energy communities, the possibility to provide aggregation or other commercial energy services, the relevant DSO to facilitate energy transfers within communities, that renewable energy communities are subject to fair, proportionate and transparent procedures, including registration and licensing procedures, and cost-reflective network charges, as well as relevant charges, levies and taxes, ensuring that they contribute, in an adequate, fair and balanced way, to the overall cost sharing of the system in line with a transparent cost-benefit analysis of distributed energy sources developed by the national competent authorities.
Electricity Market Directive (Directive 2019/944)	▪ Incentivise the clean energy transition ▪ Integrated EU energy market, secure, sustainable and affordable energy supplies to EU citizens ▪ cross-border trade and competition ▪ Active citizens contributing to the energy transition ▪ More flexible electricity markets allowing for decentralised production of electricity from renewable sources. ▪ Driving Investments ▪ Part of Clean energy for all Europeans Package ▪ Adopted in 2019, to be revised in 2024	▪ Definition of 'active customer' (Art. 2, 8; Art. 15), 'energy storage' (Art. 2, 59), 'energy storage facility' (Art. 2, 60) Rules on active customers: ▪ Art. 15, 1: final customers are entitled to act as active customers without being subject to disproportionate or discriminatory technical requirements, administrative requirements, procedures and charges, and to network charges that are not cost-reflective ▪ Art. 15, 2: active customers are entitled (directly or through aggregation) to sell self-generated electricity, to participate in flexibility schemes and energy efficiency schemes, to delegate to a third party the management of the installations required for their activities (installation, operation, data handling and maintenance), to be subject to cost-reflective, transparent and non-discriminatory network charges accounting separately for the electricity fed into and consumed from the grid, to be financially responsible for imbalances they caused in the electricity system. ▪ Art. 15, 5: Active customers owning an energy storage facility (a) have the right to a grid connection within a reasonable time after the request, provided that all necessary conditions (e.g., balancing responsibility, adequate metering) are fulfilled; (b) are not subject to any double charges, including network charges, for stored electricity remaining within their premises or when providing flexibility services to system operators; (c) are not subject to disproportionate licensing requirements or fees; (d) are allowed to provide several services simultaneously, if technically feasible. Claim for ensuring appropriate data exchange: ▪ Art. 23, 1: For the purpose of this Directive, data shall be understood to include metering and consumption data as well as data required for customer switching, demand response and other services. ▪ Art. 23, 2: Eligible parties shall have the requested data at their disposal in a non-discriminatory manner and simultaneously. Access to and relevant procedures for obtaining data shall be easy and made publicly available.

Source: European Commission (2024a, 2024b); Directive 2019/944; Directive 2018/2001; Directive 2023/24133

Appendix N (Article III): Recent contributions on state actors in governing transitions

Table 27: Recent contributions on state actors in governing transitions with emphasis on the used terms and their main research interest, own compilation.

Article	Terminology used for 'state' actors and explanation	Main research interest
Borras & Edler (2020)	**State:** Governmental action including the notions of 'government' (collective action through the exercise of legislative, executive or judicial power) and 'public policy' (concrete actions and initiatives that give concrete 'life' to the general statements/ decisions of the government)	Conceptualisation of roles of the state in the context of distinct modes of governance of socio-technical systems.
Braams et al. (2021)	**Government:** Literature review using the terms: 'government', 'state', 'ministry', 'public policy', 'administration', 'bureaucracy', 'policy makers', 'public sector', and 'civil servant'	Literature review on the transition tasks the transitions literature attributes to government. These tasks are set off against the normative arguments of the Public Administration (PA) traditions that legitimise government action.
Braams et al. (2022)	**Civil service:** Employees of the Dutch Infrastructure and Water Management (I&W) ministry	Civil servants' role perception within the institutional structures of their ministry, when executing transition tasks, in the light of Public administration traditions.
Braams et al. (2023)	**Civil service:** Employees of the Dutch Infrastructure and Water Management (I&W) ministry	Civil servants' handling of resistance and tactics to execute government transition tasks.
Borras et al. (2023)	**Public sector organisations:** Literature review including articles dealing with 'public sector organisations', which can be understood as governments, municipalities, public administrators, agencies, public actors, or similar. The authors also consider 'governance', 'policy', 'organisations' capacity'.	Conceptualisation of public sector organisations' transformative capacity (consisting of organisational roles, resources, and skills) based on a literature review.
Song et al. (2023)	**Governing entities (building on Ossenbrink et al. 2019):** Governing entities refer to the public actors 'in charge of the design, implementation, and governance of the focal policy mix' (p. 3).	Social network analysis on interactions of governing entities in the acceleration phase of transitions.
Rogge & Song (2025)	**Governing entities:** See Song et al. (2023)	Conceptualisation of framework incorporating three conceptual components – acceleration challenges, policy mix intervention points, and types of policy capacities – enabling the identification of critical capacities in the acceleration phase of sustainability transitions.

Source: Own elaboration.

Appendix O (Article III): Overview of participant observation

Table 28: Overview of working group meetings of observed industry association in the electricity system.

No.	Topic	Date
1	Energy law (working group)	Sep 2020
2	Energy politics (working group)	Sep 2020
3	Task force for EEG amendment	Sep 2020
4	Energy politics working group (presentation by member of EU parliament)	Sep 2020
5	Residential storage systems (working group)	Oct 2020
6	Finance and Investments (working group)	Oct 2020
7	Workshop on residential storage systems	Nov 2020
8	Storage technologies (working group)	Nov 2020
9	Standards and quality criteria (working group)	Nov 2020
10	Trade fair about battery storage systems	Nov 2020
11	Energy law (working group)	Dec 2020
12	Residential storage systems (working group)	Dec 2020
13	Task Force for EnWG amendment	Jan 2021
14	Energy law (working group)	Feb 2021
15	Residential storage systems (working group)	Feb 2021
16	Trade fair on residential and industry storage systems	Mar 2021
17	International market developments (working group)	Mar 2021
18	Energy law (working group)	Apr 2021
19	Energy politics (working group)	Apr 2021
20	International market development (working group)	Apr 2021
21	Workshop on storage systems and manufacturing industry	Apr 2021
22	Storage technologies (working group)	May 2021
23	Energy law (working group)	May 2021
24	Residential storage systems (working group)	Jun 2021
25	Task force Smart Meter Gateway	Jul 2021
26	Energy politics (working group)	Sep 2021
27	Energy law (working group)	Oct 2021
28	Energy law (working group)	Nov 2021
29	Storage technologies (working group)	Feb 2022
30	Energy law (working group)	Feb 2022
31	Energy law (working group)	Apr 2022
32	Residential storage systems (working group)	May 2022
33	Workshop on regulation of fast charging	Jun 2022
34	Energy law (working group)	Sep 2022
35	Storage technologies (working group)	Sep 2022
36	Residential storage systems (working group)	Sep 2022
37	Mobility (working group)	Sep 2022
38	Task force on §14a EnWG	Oct 2022
39	Energy law (working group)	Nov 2022
40	Task force residential storage systems	Jan 2023
41	Residential storage systems (working group)	Feb 2023
42	Mobility (working group)	Feb 2023
43	Energy law (working grou)	Apr 2023
44	Mobility (working group)	Apr 2023

Source: Own elaboration.

Appendix P (Article III): Relevant codes and number of coded text passages

Scheme of relevant codes including the number of coded text passages

Code	Frequency
1 Challenges	
1.1 inno_whole_syst	76
1.2 MSI	27
1.3 resist	11
1.4 contestation	6
1.4.1 intern	3
1.4.2 extern	45
1.5 user_practices	11
1.6 justice	10
1.7 intern_dyn	2
1.8 governance	
1.8.1 vertikal	21
1.8.2 horizontal	17
1.9 uncertainty	22
1.10 context Germany	19
2 Roles	
2.1 Designer	4
2.2 Initiator	0
2.3 Facilitator	4
2.4 Opportunist	3
2.5 Promoter	6
2.6 Gatekeeper	5
2.7 Moderator	5
2.8 Enabler	1
2.9 Lead-user	0
2.10 Direction	11
2.11 Watchdog	7
2.12 Mitigator	10
2.13 Warner	13
2.14 Observer	5
2.15 Guarantor	5

3 Resources	
3.1 phys_res	0
3.2 human_res	18
3.3 finan_res	3
3.4 know_res	13
3.5 legit_res	6
3.6 mandate_res	13
3.7 network_res	3
3.8 cult_res	4
4 Skills	
4.1 analytical_skills	31
4.2 operational_skills	18
4.3 coordination_skills	23
4.4 learning_skills	26
4.5 political_skills	
4.5.1 intern	8
4.5.2 extern	54

Appendix Q (Article III): Exemplary empirical material

Table 29: Exemplary interview material for acceleration challenges, regulatory implications, and regulatory state capacity (roles, abilities, and resources).

Category	Illustrative Quotes – Period 1: Focus on Maintaining	Illustrative Quotes – Period 2: Focus on Creating
Acceleration challenges	**1-WHO:** "*Because you come from an existing system and nobody really dares to tackle it. The system is based on three concepts: generation, transport, consumption. So a very clear top-down system. Coal-fired power stations and nuclear power stations produce electricity, which is transported down via the transmission network and the distribution network and consumed there. And you can still see in many regulations in energy law that this logic lies behind it and nobody has ever fundamentally tackled it [...], while our energy system has changed completely and now generation also essentially takes place at the distribution network level and implementing this in the legal framework that we have and which has also grown enormously over the last few decades is just incredibly complicated*." (Interview 12) **2-MSI:** *"If I have a PV system on a single-family house and maybe a storage unit in the basement and maybe a charging station, then theoretically I have to install up to 7-8 measuring devices. And even then in some cases is it hardly possible to keep this amount of electricity separate. That is the requirement at the moment. And there has been enourmous political pressure recently to simplify things so that these small storage facilities can also claim this exemption from the EEG surcharge in the future."* (Interview 12) *"Life is not a request concert. They [automobile manufacturers] should not overestimate their role. There are also other industry sectors, which do not want to pay their discounts."* (Interview 17) **3-DEC:** *„They [the government] actually wrote down an answer for each of these requests [for charge exemptions]. In some cases it was highly counterproductive. And that's why the rules are so incredibly complicated […] And then there was the shitstorm against the Federal Network Agency and also against the legislator: "You want everything to be so*	**1-WHO:** **"***There are approaches from individual companies […], which offer the possibility to control the storages from outside. This is going in the right direction, but we cannot estimate, don't have any figures about the share of storages, which can be controlled from outside. This is probably a small proportion."* (Interview 38) *"The underlying idea is […] that the 9 GW of small storages that we have, with a still increasing trend, could actually be helpful, if they were managed in direct marketing (Direktvermarktung), then the midday electricity is fed in, stored in, if it is not curtailed, depending on what is economically convenient, but as long as there is still room in the storage, it will be put in the storage, which helps and is also fun for direct marketers."* (Interview 39) **2-MSI:** *"That's [getting access to politics] very difficult, but of course brands like Volkswagen increase your reputation. One is taken more seriously, if you come there with a decent brand compared to three, four start-ups and SMUs."* (Interview 27) *"We hope that one day every wallbox will have the same interface, every heat pump the same interface, in order to regulate all elements with one interface. Then, for me personally, the whole topic of bidirectional vehicles is important. The regulation is really not that far yet, vehicle-to-home has been clarified, but vehicle-to-grid is a huge question mark. And also, that it will be standardised, a uniform communication protocol.. […] because it's inconvenient, if the energy management system is not compatible with the bidirectional vehicle."* (Interview 30) *„A residential storage is typically somewhere in the range between 5 and 10 kwh. An electric vehicle is by a factor of 10 higher. […] If electric cars could be operated flexibly, charged flexibly, if there was an incentive for this, we would have a much greater control potential, or flexibility potential, than with private home storage systems."* (Interview 38) *"The core problem has not been solved. The core problem is ultimately energy economic balancing of, let's say, prosumers.[…] What gets clearly more interesting and exciting with e-mobility and heat pumps […] and also regarding the new [pv] expansion speed in the energy transition. I'm optimistic that we will see a clear run-up of PV. So, that's not a question of whether we should do that, locally optimising, energy communities, energy sharing, but that this will be a technical necessity, since our infrastructure, the electricity grid, is scarce. The regulatory environment is not aligned to this speed. It is a good idea to find ways and means to deal well with this scarce infrastructure. That could be systems with storages, in particular e-mobility, if they get the corresponding signals, and I don't refer to*

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	complicated." And in truth it is like this: "You want to have such insanely complicated privileges, you want it to be like this." (Interview 14) *"You would of course have to overcome incredible resistance, because there are sectors that are strongly represented in terms of lobbying and that also benefit greatly from the current legal framework. So everyone is dependent on some kind of privilege when it comes to taxes and surcharges. So no matter what you do, you would hurt a lot of people."* (Interview 12) *"Because if I make an exception or special regulation in one place, then I have to make adjustments in 20 other places. Looking at EEG and EnWG, you have actually long since lost track. This has reached a level of complexity that is almost impossible to understand."* (Interview 12) *„So there is still the position there [BMWK and BNetzA], based on various studies that are now a few years old, that storage is not actually needed for the energy system, that it is still possible at the moment through load shifting and other methods, as long as we still have gas power plants and the like in the system, and it is cheaper to balance the fluctuations from sun and wind in other ways."* (Interview 12) *"The Federal Network Agency advises the BMWI and then we find all of these restrictive issues in the EnWG in the amendment. And then you are not only fighting against the Federal Network Agency, but also against the BMWI."* (Interview 11) *"The regulatory authority makes everything very complicated, so that it can practically no longer be understood by anyone who does not have at least 10 years of professional experience in this area."* (Interview 1) **4-EXP:** *"Regulation is now a field in which many consultants, consulting firms and law firms are active. When there is a change to the legal basis or regulations, there is a lot of contestation about it."* (Interview 17) *"The storage lobby has always made very, very high demands and always trumpeted 'Storages are not generators at all!' [...] totally insatiable, they never stop demanding."* (Interview 39) **5-CON:** *"And the Federal Network Agency has always taken an extremely negative stance on storages and self-consumption. […] They could always assert themselves, because they always thought only in economic terms.*	*price signals, which are important, but also grid signals […] we need to measure the voltage […] Then we can optimise accordingly."* (Interview 32) **3-DEC**: *"Simply because VW is putting its full lobbying power into the systems and threatening. Due to this pressure, in particular of VW, the topic of bidirectionality is maybe developed and further discussed, but there is the risk of some kind of preferential treatment, just to make VW happy, which is not actually right or relevant from a system perspective. Some kind of exemption for mobile storages is now being developed, but we don't need special regulation for mobile storages in cars, we need new regulation in general."* (Interview 35) **4-EXP:** *"I think that industry associations or a part of the industry associations are not capable of really understanding the model [electricity market design], which we currently have, and certainly don't have the courage or capability or structures whatever to explain their members what is going on here."* (Interview 39) *"Whenever the grid is involved, there is a need to check whether the grid fees for storage are appropriate. This can of course be the case with these energy communities, but we have a bit of a problem in that it is not exactly clear what these thought models and grid concepts actually are [...] It's just that the needs and concepts are actually presented to us relatively rarely in concrete terms. [...] It's just a vague general picture that is being painted that something isn't right, but it's not described in detail. And that's bad, of course, because if you want to solve a problem, you have to know what the problem looks like."* (Interview 33) *„It's simply not true. There are these EU guidelines that are so clear and that say, storages here and there, and you have to do this, they simply don't exist. Of course, this is always claimed. [...] That is the lobby tactic.*" (Interview 33) *"[...] whether it is a good strategy to demand that EU directives are not demanded. I think the strategy was bad and is bad to demand: It's written there and, thus, we want it. It's already allowed, but not practical. To say that this regulation has not been implemented, without being specific about what needs to be done, is a strategy that has not been successful in recent years and will not be successful."* (Interview 32) **5-CON:** *„The motivation of an energy transition at home is very big. Most of storage owners don't calculate it down to the last cent to see if it's really worth it. They just think it's really cool and nice when I can fill up my storage with the electricity I generate myself or charge my cell phone every day. [...] the psychological dimension of it, must not be underestimated."* (Interview 33)

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	[…] And they never understood that this is not an incentive for customers, but that customers buy all kinds of things to increase their self-consumption. They now buy heat pumps, electric vehicles. Anything what politicians want. So that they can better use the electricity they generate themselves." (Interview 11) **6-JUS:** *"It's always about optimising myself outside of the system. I continue to use all system services, but I don't pay for them. That's the motivation behind these things [residential storages]."* (Interview 14) *"Unfortunately, it is often the case that when they use electricity from the grid, they use the full amount because the sun is not shining and the storage is empty. That means that the DSO must still maintain full capacity in the grid. […] When it comes to regulation, if one doesn't pay, the other will. Then the others have to pay for the one."* (Interview 17) **8-GOV:** *"So what we can see is that the influence of European legislation is still totally underestimated in Germany. […] So far, the strategy has been to implement these guidelines in an absolutely minimal way."* (Interview 12) *"The EU is also doing good things. For example, the EEG exemption on self-consumed electricity. The limit in Germany was previously 10 KW peak, and now the limit has been raised to 30 KW peak due to the EU. That would not have happened voluntarily in Germany."* (Interview 10) *"There is this guideline about increasing the exemption from the EEG surcharge for self-consumption. The de-minimis limit has been at 10 kw for 10,000 kmw per year and in the EU regulation it says 30 kw. How we had to fight for the BMWI to simply implement this requirement one-to-one in the EEG. It really took long."* (Interview 11)	*Now, this government has tried to indoctrinate people and force them to do something. They are clearly resisting this. And that is now leading to everything being slowed down and decelerated again, so as not to scare people off any more. Finding the right pace is difficult."* (Interview 35) **6-JUS:** *„Regulation is always, one wins, one loses. There is no regulation where everyone wins. If I exempt someone from taxes, the other one pays. […] Regulation decides, who has to raise this amount x ´[to finance the grid]. A storage system doesn't have to pay this amount x. Well, then the pensioners in the rented apartment pay. these are all things that you have to think about."* (Interview 33) **7- INT:** *"Although smart meters are ultimately there to provide a certain degree of variability in electricity end-customer tariffs, then this should be harmonised across Europe […] Nevertheless, everyone understands something different about smart meters. Things, which are based on a deficient EU-legislation […] So every member state has made up its own thing."* (Interview 33) **8-GOV:** *"It is largely determined at the European level what such an energy market design should look like. There is of course a lot of scope for design at the national level, but the fundamental questions are clarified at the European level."* (Interview 32) *"No, that is not the case, what is specified will be implemented. Of course, sometimes there are questions regarding the content. And then the challenge is to implement it in such a way that you make the best of it, but to say that's nonsense, we won't implement it, that doesn't exist. We implement European guidelines to the best of our knowledge and belief. […] And I think, for example, when it comes to residential storage, it's simply the case that the level of detail in the standard doesn't require it to be regulated in one way or another." (Interview 33)* *"As far as grid tariff regulation is concerned, I have to say that the European legal framework is extremely contradictory."* (Interview 33)
Roles	*"In the documents, which we published at that time, we had already foreseen exactly the problem that I am about to describe - the so-called power peaks. […] We warned about it in time and nobody listened to us, nobody. […] We proposed this at the time because we wanted to make the expansion of solar energy future-proof; that was our argument at the time."* (Interview 39)	*"Regarding the current legal environment in EEG and EnWG, I have to say: What this government has already brought about - in terms of simplifications - we have not had that in the last 16 years. It's incredible, how fast things are possible and we are quite fascinated by the way how this is discussed right now."* (Interview 25) "*Ultimately, the task of regulation is not to dictate anything, but the task is to make things possible. So that there aren't any drawbacks, which make any concepts uneconomical per se. In this case, we would […] give a forecast of what exactly and how will be changed."* (Interview 33)

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	"In principle, you would have to imagine the energy system of the future and what it would look like and then you would have to say: "OK, we need this and that legal framework for that." (Interview 12) *"The problem [unfair grid fees] I would say is being monitored and if it continues to gain the upper hand, then we really have to consider whether there should be some kind of penalty payment for self-suppliers, some kind of contribution, similar to a building cost subsidy, we are thinking of a fixed amount to compensate so that things become fairer again overall."* (Interview 17)	*"Our department is concerned with the expansion of renewables as well as with the issue of system integration of renewables. […] That's why we're concerned with the topic of the market as well as with the topic of lines and grids. In other words, with physics and with the topic of the market. How can we obtain power in a way that is beneficial to the system, without putting any kind of cost or physical burden on the system? This now also includes the topic of PV and charging electric vehicles, which is the equivalent in the area of mobility."* (Interview 38)
Abilities	"*As a subordinate authority of the Ministry for Economic Affairs, we naturally have fairly close contact with our mother authority. We in the department are trying and putting a lot of energy into maintaining this contact very closely, also personally, actually with endless assistance and support activities, advisory services, meetings and actually personal proximity, we go there."* (Interview 14) *"And then it is passed on to the departmental coordination. That is the departmental and association hearing. So the actual way would be a departmental coordination, then an association coordination. Because things are always so incredibly hectic with the EEG, it is often done at the same time. That is structurally very bad, but that is how it is."* (Interview 14) *"We sometimes have statements with a 48-hour or 24-hour response period between Christmas and New Year. Things like that happen. With the fast-charging law, it was 48 hours between Christmas and New Year. And we have that all the time."* (Interview 16)	*"My perception has changed completely and, thus, of course my opinion, I had considered it particularly difficult at the time and now I realise, or have realised for some time, that the existence of something that can be marketed is the prerequisite for being able to do direct marketing with small systems. This mans, you need an electric vehicle, a heat pump, a storage system, you need something like that, preferably all three, to make direct marketing really fun. […] Secondly, I didn't see - and this is where I completely changed my mind - that there could actually be a mass market that would collect all of these super-small power storage units and actually integrate them into the market. I simply didn't think that was possible."* (Interview 39) *"This is now really, really demanding with this renewable [EU] directive, because it involves so many legal texts with approval rights, so many ministries and authorities. That's going to be very demanding. Each department has its responsibility for implementation, so we here in the department, we are now doing the grid integration of heat pumps, for example […] Species protection must then be done by the Ministry for the Environment. so of course you have to agree who translates what. This is again an extremely demanding process that requires a great deal of balancing and coordination."* (Interview 33) *"Very large, very good gain in knowledge in the individual topics, but the final coordination of the energy system, so to speak, as it should be and look like in the future is missing. Nobody still dares to define the overall target of what the energy system should really look like at the end of the energy transition, how sector coupling is realised in practice, how we can ultimately bring the rooftop systems and house storage and industrial storage and industrial rooftop systems into the process heat, how we want to bring this into the heat transition, how we want to bring this into mobility. There is still a very strong silo mentality, one does the Ministry of Transport, the other does the industry side in the Ministry for Economics, the other does the energy side in the Ministry."* (Interview 35) *"Nevertheless, at the moment, the Ministry for Economic Affairs is green and the Ministry of Transport is yellow. And that alone means that conflicts of interest and tensions arise because, of course, one side wants to grant the other as little as possible. Of course, they are in a coalition, but*

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		nevertheless there is a time after the coalition and everyone wants to inherit the best cards for themselves in advance. This is a very (very) big shortcoming that we have and that we have always had." (Interview 26) *"No, it [deadlines for association hearings] is still very short-term. It has improved a little over the course of the legislative period. The procedures in the ministry have become a little more well-established. Perhaps not so much is happening in parallel and at the same time anymore*." (Interview 35)
Resources	*"The BMWi does not write such regulations, especially on these topics, without consulting the BNetzA, because the BNetzA has more people and more expertise, especially when it comes to the technical details. The BMWi is already quite thin in terms of personnel, especially when it comes to the electricity department., i.e. at the moment they don't have the people to be as involved in every issue as the BNetzA. This is why, usually the BnetzA is requested. I know of many cases where BNetzA wrote the corresponding paragraphs in the EEG, including the justification for the law."* (Interview 3) *"The BNetzA was initially the wrong contact [for implementing EU legislation], but this has now changed due to the reorganisation of roles; the BNetzA is now the right contact. This was not the case before, it was the Ministry of Economic Affairs […] This combination led to the situation that some claimed implementation from the non-responsible actor*, from the BNetzA." (Interview 32)	*"This started with the fact that particularly the FDP parliamentary group in the German Bundestag pushed and pressed and pulled and did everything it could to ensure that the storage systems could actually be better integrated into the market. And they saw the so-called exclusivity principle [separation of green and conventional electricity] as their main opponent or as their main problem."* (Interview 39) *"It must be said that we had already addressed and justified all of these demands hundreds of thousands of times under the last government. […] And that is simply a completely different issue with this government. They want these topics. And if you want something, then you do those topics. […] They are now simply implementing exactly what we should have implemented at the European level a long time ago. All these pro-sumer issues."* (Interview 25) *"The BNetzA is more likely to have energy experts, but in the Ministry for Economic Affairs and Climate Action we do not necessarily have energy market experts in the departments. And the ministry itself does not actually have the competence, but the competence has to come from outside, also from the stakeholders and ultimately from the evil lobbyists."* (Interview 35) *"We proposed this rule to the ministry and the ministry thought about how to sell it to the commission, which is also very difficult. It has been difficult for the Ministry to say that the regulation we issued last year will be cancelled again this year and replaced by another one. This is also extremely complicated for the parties. That is why it is absolutely necessary to talk to the parties in advance."* (Interview 39) *"The top level has now understood, at the political level, that we need storages. […] So to speak, at a low-threshold technical level, it has also been understood, but I have to go through this very hard middle structure, […] the department, which deals with storage, these are all relatively new, young BMWK employees and now this knowledge has to be passed through this concrete block in the ministry, which says, we have never needed that and I have been sitting here for 30 years."* (Interview 35)

Source: Own elaboration.