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Phasing out Gas?

Implications of the Narratives around Natural Gas for Germany's Heat Transition in the Building Sector

Anna Kraus

Supervisor

Katharina Reindl

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Tel: +46 – 46 222 02 00.

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Abstract

Germany must decarbonise the heating of its buildings, now majorly dependent on natural gas, to meet its climate neutrality pledge. However, the share of natural gas-based heating has not been decreasing in the last decades, and Germany continuously failed to meet the building sector's emission reduction targets. Moreover, the longevity of the gas and building infrastructure make the sector prone to carbon lock-ins. Thus, the questions emerge why policies have not changed to meet the challenges of the heat transition and where the ongoing support for natural gas originates. It has been suggested that policy(ies) and socio-technical transitions are influenced by narratives and discourses, as they entail framings and goals that suggest and justify certain actions and strategies.

This thesis identifies and analyses narratives and discourses used to portray the role of natural gas in Germany's heat transition in the building sector. Further, this thesis seeks to reveal what implications these have on the heat transition, especially considering carbon lock-ins. To do so, data is collected from relevant documents and 16 semi-structured interviews with actors involved in the discussion around natural gas in the heating of buildings; and analysed using thematic analysis. A conceptual framework is employed, drawn from the literature on energy transitions, discourses, and lock-ins.

The results identify two prominent discourses: a gas discourse defending the role of natural gas, and an electrification discourse advocating for a phase-out of natural gas and the expansion of electricity-based heating. It is shown that the gas discourse coalition's strong agency has allowed them to portray gas as the central solution for Germany's heat transition, creating a discursive lock-in that can potentially prevent the dissemination of renewable heating technologies. Yet, discursive changes might also provide windows of opportunity for change. Policymakers should aim to reduce uncertainty by developing a clear strategy for a gas phase-out.

Keywords: heat transition, building sector, natural gas, narratives and discourses, lock-in effects

Executive Summary

Germany pledged to reach climate neutrality by 2045. To meet this goal, as well as to stay in line with international climate agreements, rapid decarbonisation across all sectors is needed. The building sector poses a particular challenge, as it has yet again failed to meet its emission reduction targets, and the share of fossil fuel-based heating is high, with natural gas supplying around half of Germany's demand for space heating. While the share of natural gas has not been decreasing in the last decades, renewable heating technologies are only starting to gain ground. Furthermore, the risk to create carbon lock-ins has been highlighted concerning natural gas, especially keeping in mind the longevity of the gas and building infrastructure. However, the transition from natural gas to alternative heating options, e.g., heat pumps, does not happen automatically, but rather requires careful policy design. In that sense, it has been criticised that policy measures have not been reformed to increase the uptake of renewable heating solutions and phase out fossil fuel-based heating. Thus, the questions emerge why policies have not changed to meet the challenges of the heat transition and where the ongoing support for natural gas comes from despite the risk of carbon lock-ins.

It has been suggested that policy(ies) and socio-technical transitions are influenced by narratives and discourses, as they entail framings and goals that suggest and justify certain actions and strategies. Therefore, analysing narratives and discourses can shed light on the underlying dynamics of energy transitions. Often, certain discourses are promoted by specific actor groups, which form so-called 'discourse coalitions'. These coalitions utilise and perpetuate the same discourse and the respective narratives and try to impose their view of reality on others, through debate, persuasion, but also through the exercise of power. As a result, a discursive lock-in can emerge, which means that a certain discourse reinforces the stabilisation of a socio-technical system and thus prevents the transformation away from a fossil fuel-based system.

While the influence of narratives and discourses on energy transitions as well as on the creation of lock-ins has been demonstrated in previous research, there is a lack of knowledge concerning the narratives and discourses about the role of natural gas in Germany's heat transition in the building sector and how they shape the transition and potentially create or reinforce lock-ins. This thesis aims to address this research gap, and thereby add to the understanding of how Germany's heat transition in the building sector can be accelerated. To meet this aim, two research questions (RQs) have been posed and analysed in this thesis:

> ***RQ1:*** *Which narratives are commonly used to describe the role and significance of natural gas in Germany's heat transition in the building sector?*
>
> ***RQ1a:*** *Which discourses do the narratives feed into?*
>
> ***RQ2:*** *What are the potential implications of the narratives and discourses regarding the role of natural gas for the German heat transition in the building sector, especially considering lock-in effects?*

To answer those RQs, this thesis follows a qualitative research approach, building on data collected from 16 semi-structured interviews and documents published by various actors involved in the discussion around natural gas in Germany's heat transition in the building sector. A thematic analysis supported by NVivo was performed to capture and analyse the actors' narratives and discourses in the collected data sets. To develop a deeper understanding of the role of the discourses and their interrelationships, and how they potentially shape the energy transition, a conceptual framework has been developed and employed in this thesis. The framework builds on insights from energy transition theory and the role of discourses in socio-technical transitions, as well as discursive lock-ins, and allocates discourses to the three levels of

a socio-technical system: the meta, regime, and niche level. Discursive lock-ins can emerge on all levels and lead to the stabilisation of the socio-technical system. Discursive changes, on the other hand, can also open windows of opportunity to implement change. The following figure illustrates the framework, filled with the main results from this thesis.

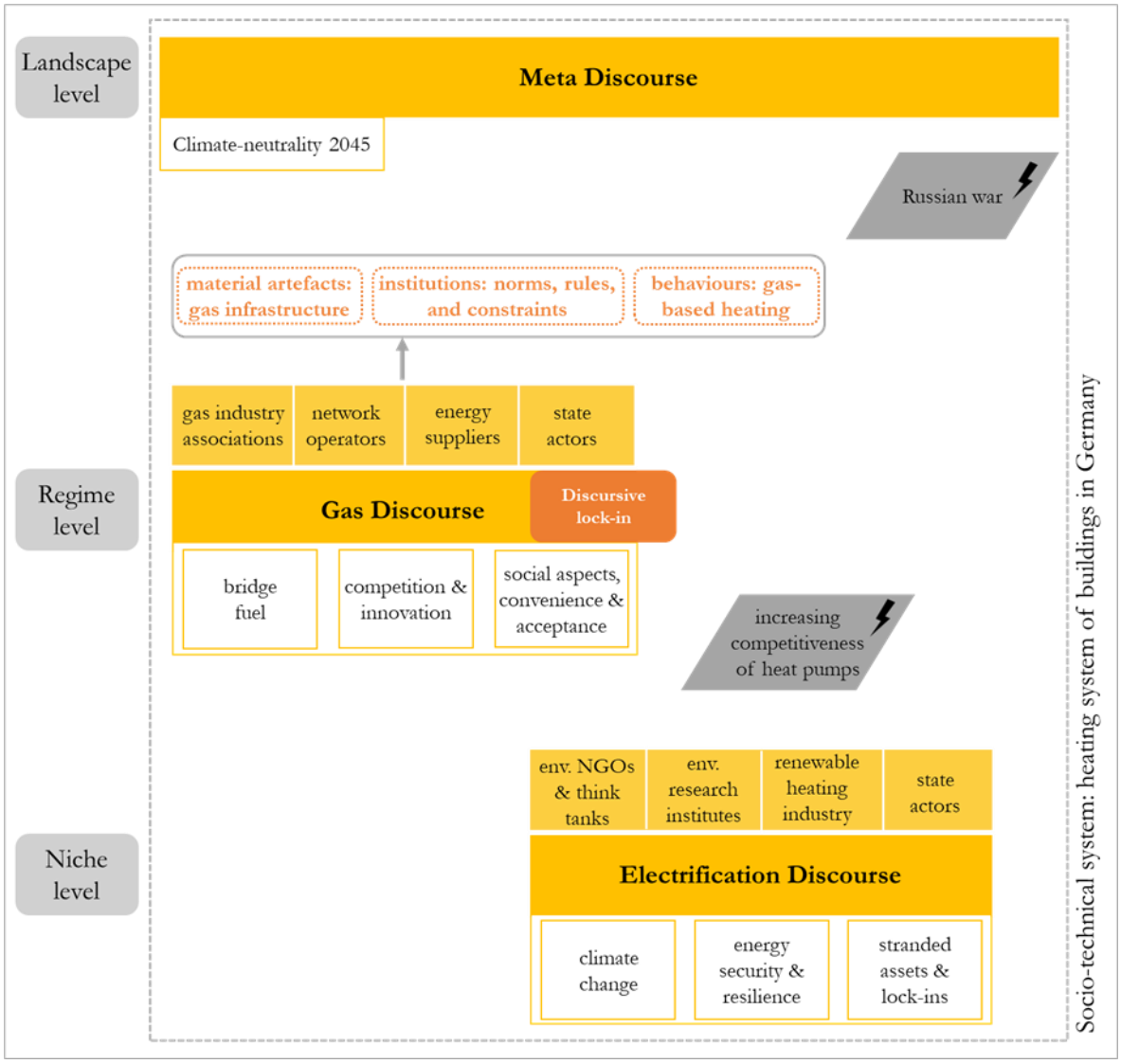

Figure 0-1. Overview of main findings: discourses, narratives, and implications for the heat transition in the German building sector

This thesis has shown that there are two prominent discourses around natural gas in the heat transition in the building sector: First, there is the gas discourse at the regime level, with the main goal to defend the status of natural gas in the heating system, and, increasingly, push for the expansion of alternative gases like hydrogen in the heating of buildings. The narratives of the gas discourse coalition are centred around the bridge fuel vision, free competition and innovation, as well as social aspects, convenience, and high acceptance. Second, at the niche level, the electrification discourse coalition is advocating for a phase-out of natural gas and the expansion of electricity-based heating. The electrification discourse coalition's narratives are strongly based on climate change, the risks of lock-ins and stranded assets, and, in reaction to the impacts of the Russian war, energy security and resilience.

Furthermore, this thesis has shown that narratives and discourses can, to some extent, explain the prolonged support for natural gas and the difficulties to accelerate the heat transition. A discursive lock-in has been identified at the regime level: The dominant gas discourse has allowed the regime actors to portray gas as the central solution for the heat transition. It has been observed that the institutionalised discourse has largely been reproduced and thereby justified and sustained the institutions, behaviours, and infrastructures of the natural gas-based heating system. Therefore, a risk to create carbon lock-ins and significantly slow down the heat transition has been identified. However, this thesis has pointed out that two discursive changes have the potential to accelerate the transition. The outbreak of the Russian war has disruptively changed the understanding of energy security and the negative consequences of fossil gas imports and thus challenged certain basic assumptions. The uncertainties around the supply of natural gas have caused increased attention across society, which could cause a higher willingness to switch to alternative heating options. Second, the increasing competitiveness of heat pumps is stimulating a dynamic discursive change. Renewable heating options like heat pumps are continuously gaining market share and attention, while the negative consequences of natural gas become better known with increasing research, especially on methane leakages. In consequence, alternative heating options might gain ground, while natural gas-based heating can lose importance. Due to the dual, mutually reinforcing discursive changes, with the disruptive discursive change drawing much attention to the risks of a natural gas-based heating system, and the dynamic discursive change strengthening the alternative discourse and providing a sense of direction for the transition, momentum is seen to accelerate the German heat transition in the building sector.

Based on the knowledge created in this thesis, the following recommendations have been formulated. This thesis has shed light on the discussion around natural gas in the building sector and therefore can help policymakers to gain a deeper understanding of the underlying dynamics of the heat transition and the interests of the actors involved. Generally, policymakers should aim to reduce uncertainty in the heating sector of buildings by developing clear strategies and guidelines for the heat transition. This is most crucial, having the contradicting discourses in mind that could lead to ambiguities for businesses and private customers alike in how to choose the heating solutions for their buildings. To break the identified carbon lock-in, it is recommended to implement regulative, economic, and informative policy measures that are targeted at a fast and determined exit strategy from natural gas while supporting the expansion of alternative heating solutions. It is also recommended to formulate a clear position concerning the use of hydrogen and other low-carbon gases in the heating sector, as otherwise, there is a risk that incumbents utilise the narrative of a hydrogen future to strengthen the position of gas in the heating of buildings. As the potential, costs, and climate impacts of hydrogen are uncertain at the moment, it is recommended to prioritise 'no-regret' measures, i.e., the expansion of heat networks and heat pumps. The findings are also relevant for businesses and private heating customers, who should critically reflect upon dominant discourses before following certain pathways, and should adapt their business models and heating technologies, respectively, to the challenges of the heat transition. Recommendations for further research are centred around two themes: First, analysing the role of and the narratives around alternative low-carbon gases like hydrogen could shed further light on the strategy behind advocating for the inclusion of those gases in Germany's heating system. Second, further research is recommended that takes the implications of the Russian war on German's energy transition into account. While this thesis has suggested that the war constitutes a disruptive discursive change that might provide a window of opportunity to accelerate the heat transition, further research in that area is needed. Potentially, studies could focus on changes in policies and the political discourse that emerged as a reaction to the war. Furthermore, studies could investigate how the public perception of natural gas and the general awareness of the German heat transition in society changed.

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Abbreviations

CO_2	Carbon Dioxide
e.g.	"exempli gratia", for example
EDC	Electrification Discourse Coalition
EU	European Union
GDC	Gas Discourse Coalition
GHG	Greenhouse Gas(es)
H_2	Hydrogen
i.e.	"id est", that is to say
kWh	Kilowatt Hours
LNG	Liquified Natural Gas
MLP	Multi-level perspective
NGO	Non-Governmental Organisation
RQ(s)	Research Question(s)
TWh	Terawatt hours
UK	United Kingdom

1 Introduction

To limit global warming to 1.5°C and thus avert the worst effects of anthropogenic climate change, the International Panel on Climate Change has stated that global net anthropogenic CO_2 emissions should reach net-zero around 2050 (IPCC, 2022). Following this impetus, a growing number of countries announced plans to achieve net-zero emissions over the coming decades (IEA, 2021). With the European Green Deal, the European Union (EU) followed suit, proposing a set of climate, energy, transport, and taxation policies to reduce net greenhouse gas (GHG) emissions by 55% until 2030 compared to 1990 levels, and to reach net-zero emissions by 2050 (European Commission, n.d.-a).

Accordingly, Germany has recently announced the goal of reaching climate neutrality by 2045 in response to a decision of the German Federal Constitutional Court in April 2021 forcing the government to raise its climate ambitions (Bundes-Klimaschutzgesetz, 2021). To reach this goal, a rapid transformation of all sectors and a great decline in the use of fossil fuels including coal, oil, and gas are needed (IEA, 2021). A lot of attention has been paid to the 'Energiewende' (energy transition) in Germany. However, most of the efforts were placed on the electricity sector, while the heating sector is discussed much less – even though large potential and need for action have been identified in the heating sector, especially in the heating of buildings (Hertle et al., 2015; Sieberg et al., 2016; Weiß et al., 2018).

The German building sector is responsible for 16% of the country's GHG emissions, and most of those emissions stem from space heating (BDEW 2020; Schrems et al., 2021). The German National Climate Change act specifies that by 2030, only 67 million tonnes of CO_2eq may be emitted in the building sector, which means that emissions must almost be halved compared to today (Schrems et al., 2021). This decarbonisation of the heating of buildings is especially challenging because up to date, the sector majorly depends on fossil fuels, mainly natural gas supplying 50% of the heating demand (see Figure 1-1).

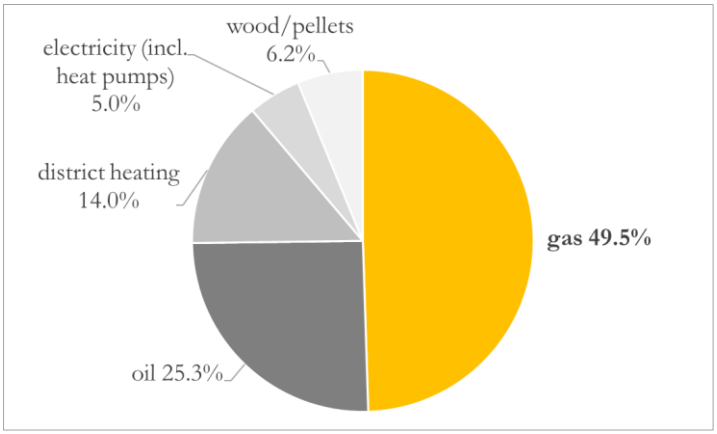

Figure 1-1. Space heating sources Germany (2019)
Source: Own presentation based on AEE (2021a)

However, substituting natural gas with alternative heating options, e.g., heat pumps, does not happen automatically but rather requires careful policy design to stimulate the transition (Weiß et al., 2021). While environmental actors have campaigned for the reform of policy measures to increase the uptake of renewable heating solutions and phase out natural gas and oil, in reality, the political landscape has not changed much (Ahmels et al., 2021). Accordingly, the level of natural gas-based heating has not decreased since 1990, making natural gas the only fossil energy source that did not decrease in Germany in this period (Ahmels et al., 2021). Thus, it has been

suggested that there is a major risk of creating carbon lock-ins concerning natural gas (Brauers, Braunger, & Jewell, 2021; Fitzgerald et al., 2019). *Carbon lock-ins* occur when path-dependencies in old, fossil fuel-based technological systems prevent the diffusion of alternative, renewable energy sources (Buschmann & Oels, 2019). Therefore, relying on natural gas for the building sector could slow down or hinder the transition to alternative heating systems.

Thus, the questions emerge why policies have not changed to meet the challenges of the heat transition and where the ongoing support for natural gas comes from despite the known risk of carbon lock-in creation. In that respect, it has been found that one way how policy(ies) can be influenced is by *narratives* and *discourses* (Hermwille, 2016; Shanahan et al., 2018). Therefore, both the literature in the field of energy transition studies, as well as studies on carbon lock-ins have highlighted the importance of analysing narratives and discourses (Geels & Verhees, 2011; Köhler et al., 2019). Narratives can be understood as a sort of storyline people make use of to illustrate and simplify complex technical constellations and interrelationships, and typically include both a problem diagnosis as well as a recommendation for action (Leipold et al., 2019; Libertson, 2021). In this study, narratives are understood as a part of a discourse, or a type of materialisation of a discourse (Leipprand et al., 2017; Urhammer & Røpke, 2013). Discourses can generally be defined as an ensemble of concepts, ideas, and categorisations that are (re)produced through actions and practices (Hajer, 1995). Often, certain discourses are promoted and shared by specific groups of actors, that form so-called 'discourse coalitions' (Hajer, 1995). Both narratives and discourses can play an important role in the policy process and can influence political action, as they entail particular framings and goals that suggest and justify certain actions and strategies (Roberts, 2017; Shanahan et al., 2011). In that sense, it has been shown that narratives and discourses can shape energy transitions and create lock-in effects (Hermwille, 2016; Simoens et al., 2022). *Discursive lock-ins* can emerge and reinforce carbon lock-ins, as following a given discourse on a topic requires less effort than forming an understanding oneself, and therefore, societal and political actors tend to follow such discourses provided by dominant actors. If that dominant discourse justifies and constitutes the institutions, behaviours, and infrastructure of a fossil fuel-based system, there is a risk to reinforce carbon lock-ins. While the influence of narratives and discourses on energy transitions as well as on the creation of lock-ins has been shown, this study will offer rigorous insights into the narratives and discourses about the role of natural gas in Germany's heat transition in the building sector and how they shape the transition and potentially create or reinforce lock-ins.

Analysing the ongoing discourses and narratives used by different coalitions can help to increase the understanding of the role of and political support for natural gas in Germany's heat transition, as well as of the risk of creating carbon lock-ins. Actors can potentially pursue a certain strategy in their framing, which in turn could impact Germany's natural gas strategy. Diverging discourses can make it difficult to reach common ground and can hinder determined political action and lead to uncertainty for heating customers.

If Germany and the EU want to stay in line with their emission reduction targets, the decisions being made in the coming years will be decisive. The transformation of the heating of buildings is especially challenging due to the variety of actors involved in heating processes and their different interests, the heterogeneity of the building structure, and the longevity of the heating infrastructure (Engelmann et al., 2021). Therefore, setting an unambiguous political frame and clear incentives will be crucial to transforming the sector and advancing Germany's heat transition (Weiß et al., 2021).

The discussions about natural gas have gained momentum in Germany because of the ongoing Russian war against Ukraine. Aside from its catastrophic humanitarian consequences, the war has led to an energy crisis in many countries that are dependent on Russian energy imports,

including Germany, with prices for gas and oil increasing significantly (IEA, 2022). This has put pressure on Germany's energy system, especially concerning the country's gas supply and energy security. As a first reaction, the government leaders have put the widely debated gas pipeline 'Nord Stream 2'[1] on hold, agreed to the construction of LNG (liquified natural gas) import terminals, and pledged to speed up the uptake of renewable energies (Amelang et al., 2022; Nasr & Marsh, 2022). Generally, it has yet to be seen what consequences the war will have on the German energy system and which pathway German politicians will decide on. However, while before the war, an exit from natural gas had been rarely discussed, the outbreak of the war has stimulated a debate about energy security and natural gas and has increased attention on the topic (Amelang et al., 2022; Fitzgerald et al., 2019). Thus, studying Germany's energy and heat system and the role of natural gas has significantly gained relevance.

1.1 Problem Definition

The identified problem to be analysed in this thesis is the urgent need to decarbonise the German heating of buildings, which is potentially hindered by certain narratives and discourses around natural gas within that heat transition. There is a lack of knowledge of the narratives used, and the discourses they feed into, around the role of natural gas in the heat transition and the impacts they might have, especially considering the risk of carbon lock-ins.

The large share of energy that is used for the space heating of Germany's buildings demonstrates the urgent need for a transformation of Germany's heating sector of buildings for the country to stay in line with both national targets and international climate agreements. Furthermore, the building sector has yet again failed to meet its emission reduction targets, and emissions have been at a stagnating high level for the past years (BMU, 2021). Against the backdrop of long investment cycles in the building sector, rapid action, ambitious goals, and planning certainty are needed for the various actors involved in the system to shape a transformation towards a GHG-neutral building stock (UBA, 2020a).

However, in Germany, natural gas is still supplying most of Germany's heat for buildings, and no downward trend is to be seen. In fact, in 2021, 653 000 out of 929 000 newly installed heating systems were natural gas-based, mostly individual gas boilers (FNB Gas, 2022a). Furthermore, a significant amount of funding is directed towards the gas infrastructure: In 2020, around three billion euros were spent on the expansion and new construction of the German gas grids (Bundesnetzagentur, 2021).

The support for natural gas is ongoing even though it is known that considering the whole lifecycle emissions, and especially due to methane leakages, natural gas has severe consequences for the environment and climate. Scholars found that natural gas might even lead to higher GHG emissions than coal or oil, depending on the assumed timeframe, plant efficiencies, leakage rates, upstream emissions, and delays in net-zero carbon technology (Gilbert & Sovacool, 2017; Hausfather, 2015). Furthermore, it was found that the great dependency on natural gas for heating could dangerously slow down the heat transition, especially when it comes to lock-in effects (Brauers, Braunger, & Jewell, 2021). For instance, investments in natural gas can prevent investments in renewable heating sources, and existing fossil fuel infrastructures can hamper advances in renewable technologies (Gürsan & de Gooyert, 2021).

[1] Nord Stream 2 is a new gas pipeline from Russia to north-eastern Germany, designed to double the amount of natural gas flowing from Russia straight to Germany. While its construction was finalised in September 2021, it has not started operating yet due to the lack of approval from European regulators (BBC, 2022).

The relevance of taking on an interpretative or constructivist approach to energy transition and lock-in research, such as analysing narratives and discourses, has been demonstrated by various scholars, also for the context of the German energy transition and the support for natural gas (Geels & Verhees, 2011; McBeth et al., 2014; Shanahan et al., 2011; Sovacool & Hess, 2017). For instance, Brauers, Braunger, & Jewell (2021) found that political lobbying, which includes the use of certain narratives, explains the ongoing investments into gas infrastructure at least to some extent, as well as pressure from a variety of private and state actors. Buschmann & Oels (2019) observed that for the German energy transition, discourses played a part in both creating and overcoming carbon lock-ins. Delborne et al. (2020) found that the 'bridge fuel'[2] narrative of natural gas portraying it as a clean transition fuel is still predominant, thereby justifying ongoing political support. And Fitzgerald et al. (2019) found that certain discourses around natural gas contribute to creating carbon lock-ins in Germany.

However, while there is some research on narratives and discourses on natural gas and the risks of carbon lock-ins in general, an analysis of the narratives and discourses around natural gas within Germany's heat transition in the building sector does not exist. Furthermore, to date, it is not known if and to what extent narratives and discourses shape the heat transition and potentially add to the creation of gas lock-ins for the building sector. Analysing the implications of the utilised narratives and discourses will also help to gain clarity on which political measures are needed to accelerate the heat transition and navigate the various actors' interests. Thus, this thesis entails high practical relevance, especially for policymakers, but also for businesses and building owners, as they profit from clear communication and a strategy on the heat transition that reduces the uncertainty in making investment decisions in heating technologies. Furthermore, this thesis offers rigorous insights for academia by adding to the literature on narratives and discourses around natural gas and developing a framework combining transition theory, discourse and narrative analysis, and lock-ins.

Lastly, the political crisis resulting from the Russian war on Ukraine sheds new light on the discussion around natural gas, which implications have not been researched yet. Thus, this thesis also offers insights into those recent developments and the implications for Germany's energy transition.

1.2 Aim and Research Questions

This thesis has the general aim to add to the understanding of how Germany's heat transition in the building sector can be accelerated. There is a lack of knowledge concerning the narratives and discourses about the role of natural gas in Germany's heat transition in the building sector and how they shape the transition and potentially create or reinforce lock-ins. This thesis aims to address this research gap. Identifying and dismantling the various narratives and the discourses they feed into will help to gain a deeper understanding of the underlying dynamics and developments in the German gas and heating sector. Furthermore, analysing the implications of those discourses on the heat transition will allow for the identification of discursive lock-ins, that can potentially prevent the dissemination of renewable heating technologies and thus slow down the transition.

First, this thesis aims to identify and analyse dominant narratives and the discourses they feed into used to portray the role of natural gas in Germany's heat transition of the building sector. As narratives can be understood as a part of a bigger discourse, identifying the narratives of a certain discourse helps to create a better understanding of that particular discourse. In that

[2] A bridge fuel in this case refers to a low(er)-carbon fuel (natural gas) that substitutes a high-carbon fuel (mostly coal and oil) to reduce emissions in the nearer future (Gürsan & de Gooyert, 2021).

sense, narratives are more specific, while in contrast, discourses are the broader, more general part, that entail a certain understanding of the desired outcome. Discourses bundle the narratives together and provide a sense of direction for the actors.

Building on the identified narratives and discourses, this thesis seeks to reveal what implications these have on the heat transition in the building sector. Theory on discourses in energy transitions suggests that discourses can reinforce carbon lock-ins when the predominant discourse justifies and constitutes the fossil fuel-based system, creating a discursive lock-in effect (Simoens et al., 2022). In this context, this means that since forming an understanding of the complex interplay between environmental, social, technical, economic, and political factors around natural gas is very complicated, people might prefer to follow the discourse provided by the credible regime actors, as that requires less effort than forming an understanding themselves. Thus, by focusing on the risk of discursive lock-ins, it can be analysed if discourses reinforce the stabilisation of a socio-technical system and thus prevent the transformation away from a fossil fuel-based system, i.e., create carbon lock-ins. However, discourses also entail the power to challenge the status quo and overcome lock-ins if it comes to discursive changes. Thus, the potential implications of discursive changes on the German heat transition are also analysed.

Based on the research aim, two research questions (RQs) have been formulated to be answered in this thesis. Their structure is loosely hierarchical; meaning the answer of the first RQ contributes to answering the second.

> ***RQ1:*** *Which narratives are commonly used to describe the role and significance of natural gas in Germany's heat transition in the building sector?*
>
> ***RQ1a:*** *Which discourses do the narratives feed into?*
>
> ***RQ2:*** *What are the potential implications of the narratives and discourses regarding the role of natural gas for the German heat transition in the building sector, especially considering lock-in effects?*

Figure 1-2. Research Questions

The narratives and discourses are identified by conducting interviews with multiple actors involved in the discussion around natural gas in Germany's heat transition in the building sector as well as the analysis of relevant documents. Subsequently, the implications and the risk of the creation of lock-ins are analysed, building on a framework combining different types of discourses with discursive lock-in analysis. Based on the findings, this thesis seeks to formulate practical recommendations on how to accelerate the heat transition in the German building sector, having the formation of carbon lock-ins and the influence of discourses on that phenomenon in mind. Furthermore, areas for further research are identified.

1.3 Scope and Delimitations

This study is focused on the role of natural gas in Germany's building sector and the narratives and discourses of relevant actors at a German level. It must be acknowledged that focusing on gas used only in the heating of buildings poses a challenge to the study. As gas is also used in other sectors including industrial processes, the chemical industry, electricity, or transport, the gas infrastructure, i.e., the gas grid and transmission pipelines, gas storage, and LNG import terminals, is used for those applications as well. Thus, strictly distinguishing what part of that infrastructure is used for the heating of buildings and what part for the other applications is not possible, and synergies between the different sectors exist that influence the need for gas and gas infrastructure. This needs to be considered when looking at the creation of lock-ins. The geographical scope of this master's thesis is set on Germany, even though policymaking at the

EU level, as well as international developments, also shape Germany's energy system. Actors included in the analysis are from the German context only, and this thesis focuses on the national level discussion in Germany. Furthermore, the focus is on the role of gas as one part of the heat transition. Other necessary measures, like the promotion of alternative heating sources to replace gas, e.g., heat pumps and district heating, and the necessary increase in building refurbishment, are only marginally touched upon. With regards to the timeframe, this thesis focuses mostly on recent developments and thus covers documents published mostly between 2021 and 2022 as well as interviews conducted in 2022. Lastly, it should be acknowledged that the focus of this thesis is on natural gas, and other gases, e.g., hydrogen and biogas, are not focussed on. However, since the topic of hydrogen was very present within the collected data of this thesis, hydrogen is included marginally. Biogas, on the other hand, is excluded from the analysis. While it is acknowledged that it is and should be part of the discussion around the role of gas in the heating of buildings, it is not within the scope of this thesis.

1.4 Ethical Considerations

This thesis was conducted in times of the outbreak of the Russian war against Ukraine. The author acknowledges the devastating social and human consequences of the war. People's personal lives, as well as political and economic relationships within and between countries, have been dramatically shaken, disrupted, and changed. In light of the close connection between fossil energy sources, particularly natural gas, and the ongoing conflict, recent developments must be taken into account for this research. Data collection in form of interviews has been conducted right after the outbreak of the war at the beginning of March and has impacted the results. This is acknowledged and further elaborated in the discussion section

Ethical considerations regarding the interviews were considered. Participation in the interviews was completely voluntary and under informed consent and understanding of the right to withdraw. Participants were informed about the aim of the research and how the information they provide would feed into the analysis. Names and organisations were anonymised; participants were only referred to as representatives of their respective actor groups. It is not expected that the results of the research would cause any negative consequences for participants. No sensitive data was collected. The collected data was stored on the researcher's computer which is password protected and only accessible to the researcher. The author did not receive any funding and was not under influence of any person or organisation which might influence the analysis. The research was reviewed against the criteria for research requiring an ethics board review at Lund University and has been found to not require a statement from the ethics committee.

1.5 Audience

The main audience of the study at hand are policymakers advancing the heat transition in the building sector. Furthermore, it is relevant for practitioners like businesses, as well as for end customers and researchers in the field of the heat transition of the building sector.

For policymakers, it will be crucial to come up with detailed plans and policies on how the heat transition in Germany's building sector can be facilitated. This is important to stay in line with Germany's national climate plans as well as international climate agreements. Gaining an understanding of the interests of various actors in the heat transition regarding natural gas will help policymakers both to understand potential lobbying strategies as well as to navigate different actors' interests. Having in mind the longevity of heating infrastructure and the great dependency on gas today on the one hand, but also the necessity of a phase-out of natural gas sooner or later to stay in line with emission reduction targets, on the other hand, fast action

from policymakers will be needed. It is also in their interest to avoid sunk investments, as otherwise, the government will need to pay for transitions, compensations, and indemnities. Thus, policymakers will profit from the knowledge of the risk of carbon lock-ins. Furthermore, insights into dominant discourses will help policymakers to design their communication strategies accordingly, i.e., either utilise discourses that are in line with the necessary measures to advance the German heat transition, or challenge discourses that prevent this change.

Furthermore, the topic is relevant to businesses, such as energy providers, gas network operators, or heating technology manufacturers. In case of a gas phase-out, they will need to plan the transition and decide on their budgets to avoid sunk investments. Heating customers will also profit from a clear discussion around the role of gas. Low gas prices might set misleading incentives, and heating customers need clear signals for how they should plan potential changes in their heating systems. Lastly, other practitioners working on advancing the heat transition, for instance, non-governmental organisations (NGOs), profit from insights on dominant discourses they can utilise or challenge to induce change.

On an academic level, this thesis contributes to the current body of knowledge on the heat transition in the building sector. It offers rigorous insights into the narratives and discourses used in the German heat transition in the building sector focusing on natural gas, and the implications of them on the heat transition, especially concerning lock-in creation. Furthermore, a theoretical contribution is made by elaborating a framework based on the concepts of narratives and discourses, transition theory, and lock-ins.

1.6 Disposition

Chapter 1 describes the background and significance of the topic of this thesis. The research problem as well as the research aim and research questions are defined, as well as the scope and delimitations. Furthermore, the intended audience, ethical considerations, and the disposition of this thesis are outlined. *Chapter 2* provides relevant background information on the use of natural gas and Germany's building sector. *Chapter 3* presents a literature review that outlines the current knowledge concerning the research topic, concluding with an identification of a research gap that this thesis aims to address. *Chapter 4* reviews relevant concepts and frameworks and describes the conceptual framework that has been developed and employed in this thesis. *Chapter 5* outlines the research design and methodology for data collection and analysis. *Chapter 6* presents the main findings of the research as well as an analysis of those findings. *Chapter 7* discusses the main findings of this thesis linked back to existing research in the area and points out the limitations of the work. *Chapter 8* concludes this thesis by providing answers to the research questions and discussing practical implications and recommendations for non-academic audiences. Recommendations for future research are made.

2 Background – Natural Gas in Germany's Building Sector

This chapter provides background information relevant to the topic, starting with general information about natural gas and its use and infrastructure in Germany. Second, information about Germany's building stock, as well as decarbonisation pathways, and policy instruments relevant to the building sector are presented.

2.1 General Information about Natural Gas

Natural gas, a naturally gaseous hydrocarbon mixture primarily made up of methane, is a fossil energy source used worldwide (Faramawy et al., 2016). With a wide range of possible uses, including heat and electricity generation, as a raw material in the chemical industry, or as a possibility to store energy, natural gas plays an important role in the global energy supply (BMWi, 2021; Economides & Wood, 2009). With global energy demand increasing, the use of natural gas has drastically increased for over half a century, and CO_2 emissions from natural gas are currently the fastest-growing source of global fossil fuel emissions (Peters et al., 2020).

The rise of natural gas can be explained by its high energy conversion efficiencies for power generation, its versatility, and relatively low costs for end customers (Economides & Wood, 2009). While the Russian war and the connected energy crisis have a major influence on the current prices of gas and oil, the average prices for 2020 give a good indication of the price differences for end customers before those political developments: While oil and natural gas cost about 4.6 cents/kWh and 6.0 cents/kWh respectively, electricity prices, e.g., to run a heat pump, were at 22.8 cents/kWh (co2online, n.d.-a). Furthermore, it was long said that natural gas was the most climate-friendly fossil energy source, emitting about 40% less CO_2 than coal per unit of energy in the burning process (Hausfather, 2015; Peters et al., 2020). Thus, it was seen as a bridge solution to reduce carbon emissions in the short term by switching from coal and oil to natural gas (Economides & Wood, 2009; Hausfather, 2015).

However, as more recent studies show, accounting for lifecycle emissions of natural gas relativises the apparent benefit (Alvarez et al., 2012, 2018; Gilbert & Sovacool, 2017; Hausfather, 2015; Howarth, 2014). Especially methane leakages from natural gas infrastructure lead to high GHG emissions over the full lifecycle (Alvarez et al., 2012). Thus, scholars found that natural gas might even lead to higher GHG emissions than coal or oil, depending on the assumed timeframe, plant efficiencies, leakage rates, upstream emissions, and delays in net-zero carbon technology (Gilbert & Sovacool, 2017; Hausfather, 2015). Howarth (2014), for instance, used 20 years for the calculations, arguing that this is appropriate given the urgent need to decrease methane emissions in the next decades. With that assumption, the author finds that "both shale gas and conventional natural gas have a larger GHG than do coal or oil, for any possible use of natural gas and particularly for the primary uses of residential and commercial heating" (Howarth, 2014, p. 47). However, using shorter timeframes for such calculations is not a common practice, and most of the official calculations usually do not consider the short-term effects, leading to too low estimations (Ahmels et al., 2021).

There are other types of gas which are being discussed also as a replacement for natural gas in the building sector. First, there is *biogas*, commonly produced from either wastes or purpose-grown crops. While it is classified as a renewable gas (International Council on Clean Transportation, 2019), there are growing concerns about its environmental impact, especially because of its large land use and the connected impacts (UBA, 2020b). Thus, it is said that biomass, especially purpose-grown crops, should be prioritised for material uses, such as replacement material in construction, and only used in heating if there are no other alternatives (UBA, 2020b). Furthermore, different forms of *hydrogen* are increasingly discussed, mostly grey,

blue, and green hydrogen. Grey hydrogen has the highest CO_2 emissions. It is generated from natural gas or coal through a so-called 'steam reforming' process, during which CO_2 and carbon monoxide emissions are generated. Blue hydrogen stems from the same sources as grey hydrogen, however, carbon capture and storage is used to store the generated carbon underground. However, it needs to be acknowledged that usually only 80-90% of the generated carbon can be captured. Lastly, green hydrogen is produced by splitting water into two hydrogen atoms and one oxygen atom via electrolysis. The process is powered by surplus renewable energy sources, and thus, green hydrogen is seen as a way to utilise excess energy produced during peak times that cannot be used as electricity directly (World Economic Forum, 2021). While green hydrogen currently only makes up about 0.1% of overall hydrogen production, it is expected to rise with decreasing costs of renewable energy (World Economic Forum, 2021).

2.2 Use and Infrastructure of Natural Gas in Germany

Germany, together with the UK and Italy, make up the biggest markets for natural gas in Europe (BMWi, 2021). Almost all of the natural gas in Germany is imported, primarily from Russia (67%), Norway (21%) and the Netherlands (12%) (Bundesnetzagentur, 2021). Natural gas, after oil, is Germany's second most important primary energy source, supplying 24.3% of Germany's final energy use (AGEB, 2021; BMWi, 2021). In contrast to other fossil energy sources, that amount did not decrease since 1990 (Ahmels et al., 2021). Natural gas is mostly used for the heating of buildings, but also process heating and cooling in industry, and the generation of mechanical energy (AEE, 2021b; AGEB, 2021).

Germany has a substantial gas infrastructure used to distribute gas within the country but also to other EU states, with 42 000 km of the long-distance grid, and 554 400 km of distributing grid (Bundesnetzagentur, 2021). Additionally, natural gas processing facilities and storage and transport facilities, are part of the gas infrastructure. Following the current developments in Russia, plans to build at least two LNG import terminals in Germany, which have been discussed for years, are now concretising, while the operating permission of the Nord Stream 2 pipeline has been put on hold (BBC, 2022; FNB Gas, 2022b).

2.3 Germany's Building Sector

2.3.1 Characteristics and Climate Goals

The German building sector is responsible for 16% of the country's GHG emissions (BMWK, 2021). Most of the energy demand in buildings is caused by space heating and hot water. Space heating accounts for 26.5% of Germany's final energy use (see Figure 2-1) (AEE, 2020).

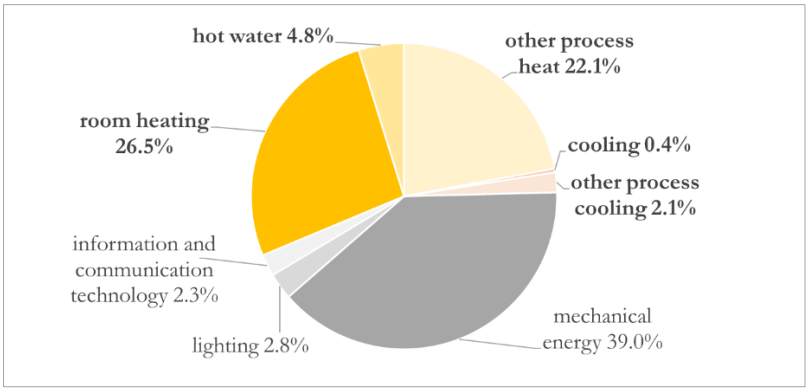

Figure 2-1. Final energy use in Germany (2018)
Source: Own presentation based on AEE (2020)

Having the high share of fossil energy sources for heating in mind, there is both the need and large potential for emission reductions. Until 2050, the German government seeks to achieve a 'nearly climate neutral' building stock (BMWK, 2022). By 2030, as specified by the German National Climate Change act, only 67 million tonnes of CO_2eq may be emitted in the building sector (Bundes-Klimaschutzgesetz, 2021). As the current levels are at about 120 million tonnes of CO_2eq in 2020, that means that emissions must almost be halved compared to today (Die Bundesregierung, 2022b). This is challenging, looking at the characteristics of the German building sector.

Germany's building sector consists of a heterogeneous mix of dwellings. According to the Germany's energy agency's 2022 report (dena, 2021a) and the micro-census of the German federal statistical office (Statistisches Bundesamt & Destatis, 2014), the following numbers are known about Germany's buildings: Out of the total of around 19 million residential buildings in Germany, about 13 million are single houses, 3.2 million are semi-detached houses, and 3.3 million are multi-flat houses. In total, in all buildings, there are around 42.8 million housing units. In 2019, around 113 000 new residential buildings were built, representing a yearly growth rate of the building stock of 0.57% for single-family houses and 0.54% for multi-flat houses. In contrast to residential buildings, there is no official figure for the number of non-residential buildings. However, extrapolations estimate that there are around 1.98 million heated non-residential buildings.

Most of the buildings in Germany, about 70% of residential buildings and 60% of non-residential buildings, have been built before the first German thermal insulation ordinance (Wärmeschutzverordnung) in 1977. Another 25% of the buildings have been built between 1978 and 2001, and only about 6% after that (co2online: Wohnen und Sanieren, n.d.). Thus, while energy standards for new buildings are important, the most potential for energy performance and efficiency improvements is seen in the building stock, where energy standards are in most cases low (UBA & co2online, 2019). It is estimated that 70-75% of the buildings built before 1979 have not yet undergone any building envelope refurbishment and are thus not insulated at all or insufficiently insulated (UBA & co2online, 2019). Those uninsulated buildings use more than up to 52% of energy for heating compared to, e.g., the buildings that have been fully insulated and use solar thermal energy (UBA & co2online, 2019). Thus, there is considerable potential for energy savings in the building stock, and the continuous promotion of ambitious, energy-efficient renovations of the building stock is essential for Germany to meet the emission reduction goals in the building sector. However, the refurbishment rate for buildings has been stagnating at about 1% per year for the past decade, while a rate of at least 2-3% would be needed to meet Germany's climate goals (UBA, 2020a). Besides refurbishment of the building envelope, large potentials for emission savings are seen in the heat technologies, by improving existing technology or the use of renewable energies (BMWi, 2019).

Looking at the heating technologies of buildings, the important role of natural gas becomes evident, with natural gas accounting for approximately 49% of the energy supply for space heating (AEE, 2021a). Oil accounts for another 25% of the energy supply for heating, and electricity, including heat pumps, only for about 5% (AEE, 2021a). With annual replacement rates of 2.5 to 3 % for heating technologies in buildings, the rate is slightly higher than the building refurbishment rate. However, in 2021, out of 929 000 newly installed heating systems, 653 000, i.e., 70%, were gas-based, mostly individual gas boilers (FNB Gas, 2022a). The average lifetime for a gas boiler in Germany is 24 years (co2online, n.d.-a). Thus, the gas boilers being installed today will stay in Germany's building stock for a considerable amount of time.

2.3.2 Decarbonisation Pathways

Several studies examine pathways for the German energy transition, including the transition of Germany's building sector (e.g., Blesl et al., 2018; dena, 2018; Fraunhofer IWES/IBP, 2017). Furthermore, other studies more specifically model the future natural gas demand in Germany (Hainsch et al., 2020; Maier, 2019; Oei et al., 2019; Wachsmuth et al., 2019). However, as the goal to reach climate neutrality by 2045 has only been announced very recently, most of the currently available studies do not take the new target of climate neutrality by 2045 into account, but instead, refer to the previous target of climate neutrality by 2050. Therefore, two studies that consider the 2045-goal were chosen for further examination: (1) the study "Climate neutral Germany 2045" by Prognos, Öko-Institut, and Wuppertal-Institut (2021), and (2) the German energy agency's lead study "The road to climate neutrality" (dena, 2021b). In the following, the main results are presented.

(1) The study "Climate neutral Germany 2045" concludes that for the scenario to reach the 2045 climate neutrality goal, changes in the heating structure, the expansion of heat networks, and an increase in the energy refurbishment rates will be essential for the transition of the building sector. Final energy demand in the building sector will decrease substantially due to efficiency improvements and electrification. By 2025, the refurbishment rate should reach 1.6% per year, 6 million heat pumps should be installed, and new heating systems based on oil or natural gas should only be commissioned in a few exceptional cases. By 2045, the refurbishment rate should have reached 1.75% per year, which results in over 90% of the living space being renovated (or newly built) in the year 2050. Between 2030 and 2045, on average, 340 000 flats per year will be connected to a heat network, and 920 000 flats per year will be equipped with a heat pump. This increases the total number of heat pumps to 14 million by 2045. Through these measures and developments, most fossil heat generators will have been replaced in 2045. For natural gas, this means that on average, natural gas heating systems will be decommissioned in 990 000 flats per year. While a small number of buildings will still be equipped with gas-based heating systems by 2045, those will be exclusively fuelled by biogas, which will be completely phased out by 2050. Hydrogen or synthetic gases, in general, will not be used in the building sector due to their high costs. Importantly, with regards to gas grids, the study highlights that due to the strong reduction of gas heating in the building sector, the costs for the operation and maintenance of the gas networks will be distributed amongst fewer and fewer end customers. This makes the use of gas increasingly uneconomical for the remaining customers. It is to be expected that the operation of the distribution grids for natural gas will not be maintained if only a few customers are still being connected, but that grid sections will be successively shut down when the capacity utilisation falls below a certain threshold.

(2) The study "The road to climate neutrality" also highlights the importance of energy efficiency improvements through increased refurbishment rates as well as changes in heating technologies. While the study includes multiple scenarios, the main scenario (KN100) suggests the following. With regards to the refurbishment rate, they estimate that by 2031, an average of 1.90% per year will be needed, which should remain at that level until 2045. Furthermore, the study also deems an increasing number of buildings connected to a heat network, as well as an increasing number of installed heat pumps necessary. They say that 4 million heat pumps should be installed by 2030, and 9 million by 2045. The lower numbers in comparison to the study "Climate neutral Germany 2045" can be explained by the fact that they still expect a certain amount of gas-based heating systems, by 2030 primarily biogas, but after that also increasingly hydrogen. They say that by 2045, there will be some quantities of hydrogen and biogas, but about 11 TWh of fossil natural gas will remain in the system. By 2050, natural gas should be phased out completely. To avoid lock-in effects, they say that from 2025 on, new non-electricity-based heating systems (e.g., condensing boilers, fuel cells,) should be 'H_2-ready'. However, they also acknowledge the

need to monitor how the market situation for hydrogen in the building sector develops in terms of availability, quantities, and costs over the next years.

While the studies differ in their exact pathways and energy mixes for the heating in buildings for 2045, both studies assume a significant decrease of natural gas-based heating systems to a complete phase-out by 2050 at the latest. Furthermore, both studies consider heat pumps and decarbonised heat networks as playing a crucial part.

2.3.3 Policy Instruments

The decarbonisation pathways generally assume a significant decrease in the use of natural gas, besides energy efficiency improvements. Thus, policy instruments to incentivise this transition are needed. Multiple policy instruments exist in Germany to accelerate the transition in the building sector, aiming both at increasing refurbishment rates as well as substitution of heating technologies (BMWK, 2022). Relevant for gas specifically are the federal subsidies for efficient buildings (Bundesförderung für effiziente Gebäude, BEG): Heating systems solely based on gas were exempted from federal subsidies since 2019 (BAFA, 2022). However, the instalment of hybrid heating systems, i.e., a heating system combining a gas boiler with a renewable heating system such as a heat pump, as well as 'renewable ready' heating systems, is still subsidised (BAFA, 2022; FNB Gas, 2021b; KfW, 2022). Table 2-1 gives an overview of existing policy instruments in the building sector:

Table 2-1. Overview of most important policy instruments in the building sector in Germany (2022)

Informative	Administrative/regulatory	Economic / market-based
Energy consultancy: - Consumer advice centre - On-site consultation with energy efficiency experts - Individual renovation roadmap (iSFP) Information campaigns Research and pilot projects	Building Energy Act (Gebäudeenergiegesetz): energy requirements for new and existing buildings and energy requirements for the use of renewable energies for heating and cooling EU law (e.g., Energy performance of buildings directive) Tenancy law	Federal subsidies, e.g.: - Subsidies for efficient buildings - Renewable energies premium – subsidies and loans (KfW and BAfA) - Subsidies for heat networks Emissions trading for the heat and transport sectors (Brennstoffemissionshandelsgesetz) Taxes, e.g.: - Energy and electricity tax - Tax incentives for refurbishment and energy efficiency improvements

Source: Own presentation based on: BMWi (2019); BMWK (2022); Deutscher Bundestag (2020); Die Bundesregierung (2022a); European Commission (n.d.-b); and Henger et al. (2017)

The coalition agreement of the newly formed German Government gives some indications about planned policy changes concerning the building sector and heating systems. Importantly, the new government announced that from 2025 on, every newly installed heating system has to be operated on at least 65% renewable energies (Koalitionsvertrag 2021-2025, 2021). Furthermore, they emphasise the need to increase the share of renewable energies in the heating sector and the necessity to expand heat networks, to reach a share of 50% climate neutral energy sources for heating by 2030. In reaction to the high energy prices and the insecurity of energy supply resulting from the Russian war, the government announced some recent policy measures aimed at reducing the gas demands: The 65% renewable energy obligation for newly installed heating systems will be introduced from 2024 on already. Furthermore, the uptake of heat pumps to replace gas boilers will be subsidised (BMF, 2022).

3 Literature Review

The literature review aims at identifying and discussing gaps in the literature that the study at hand contributes to addressing. To achieve that goal, a semi-structured literature review was performed, covering the literature from various fields that were deemed to be relevant for this thesis. Academic, peer-reviewed, open-access journal articles and book chapters in English were included in the review, complemented by grey literature, especially reports from environmental research institutes and environmental organisations. Different search string combinations were applied in in Scopus, Google Scholar, and LUBsearch. The general goal was to gain an overview of the discussion around natural gas in Germany's heat transition in the building sector, the risk of lock-ins connected to natural gas, as well as of the current knowledge on narratives and discourses about natural gas.

The first focus of the literature review was on Germany's energy and heat transition because the topic of this thesis falls broadly within the transition literature, and it was relevant to gain a general overview of the discussion around the transition in the German context. Furthermore, the role of natural gas within that transition was reviewed. Search string combinations included the keywords *Germany – energy transition – socio-technical transitions – heat transition – building sector – natural gas*. Second, the literature on carbon lock-ins was analysed, specifically with a focus on natural gas, including the following keywords: *carbon lock-ins – lock-in effects – natural gas*. Subsequently, the literature on narratives and discourses about natural gas was reviewed. Search string combinations included the keywords *narratives – discourses – political discourse – natural gas*. Lastly, the focus was set on the interlinkage between narratives and discourses and transition theory, by applying search string combinations including *interpretative and constructivist transition analysis – narratives – discourses – transition theory*. This resulted in a general overview of the topics relevant to this thesis, which allowed for the identification of research gaps (described in section 3.5), and the development of a conceptual framework (described in chapter 4).

3.1 Energy and Heat Transition and the Role of Gas

Energy transitions generally refer to "the transition in energy supply from fossil fuels and nuclear energy to renewable energies, in all three major energy-consuming sectors: electricity, heat and transportation" (Unnerstall, 2017, p. 13). The literature on energy transitions usually comes from various disciplines, including sociology, political science, economics, and technology (Cherp et al., 2018).

In Germany, the discussion and accompanying literature around the *German 'Energiewende'* (energy transition) go back to the early 1980s. However, as a reaction to the nuclear catastrophe in Fukushima in 2010 and Germany's decision to exit nuclear power, momentum increased for the German Energiewende, leading to a vast increase of literature on the topic (co2online, n.d.-b). Furthermore, there is a large amount of literature that discusses Germany's exit from nuclear power (e.g., Jahn & Korolczuk, 2012; Keppler, 2012; Knopf et al., 2011; Rehner & McCauley, 2016) and from coal (e.g., Baudisch & Fouquet, 2019; Kittel et al., 2020; Schumann et al., 2016). However, as different scholars pointed out, the majority of the literature on the German energy transition and the coal and nuclear exit has been focused on electricity and not on heating, even though heating makes up for almost half of Germany's final energy needs (Hertle et al., 2015; Sieberg et al., 2016; Weiß et al., 2018). These scholars all point out a further need for research on how the heat transition can be accelerated.

Looking at the *German heat transition*, the scientific literature commonly lists some specific challenges the heat transition in the building sector poses: First, the heterogeneity of the German building stock, as well as the multitude of actors involved, does not allow a 'one-size fits all' approach, but rather a variety of solutions are needed (Engelmann et al., 2021; Frank et al., 2020;

UBA, 2020a; Weiß et al., 2018). Furthermore, with regards to policy measures in the building sector, a lack of acceptance is often mentioned as a hindrance, as well as incentive problems, especially between renters and property owners (Gawel et al., 2014). When looking at literature on pathways for Germany's heat transition, studies are mostly found in the grey literature (dena, 2021b; Prognos et al., 2021), which is described in more detail in the background section (section 2.3.2). Commonly, the studies assume a significant decrease of natural gas-based heating systems to a complete phase-out by 2050 at the latest (dena, 2021b; Prognos et al., 2021). Furthermore, the studies consider heat pumps and decarbonised heat networks to play a crucial part in Germany's future heating (dena, 2021b; Prognos et al., 2021). In the following, an overview of the academic literature on the heat transition is provided, that focuses on the role of natural gas, alternative gases, as well as heat pumps and heat networks. Thus, the studies generally do not employ a holistic approach, but rather focus on the role and potential of specific technologies.

The literature on the *role of natural gas* in the energy and heat transition was reviewed. Providing an overview of the advantages and disadvantages commonly referred to in literature, Gürsan and de Gooyert (2021) performed a literature review to analyse whether natural gas hinders or accelerates energy transitions. Positive effects of natural gas include energy reliability and flexibility, and reduced transition costs. Negative effects include the crowd-out of renewable energy alternatives, carbon lock-ins, higher emissions, and environmental effects. Their research concludes that there is a substantial risk that natural gas can delay the energy transition globally, which outweighs positive immediate and local benefits. With regards to a discussion around *natural gas in Germany's heat transition*, it can be said that the topic has been given less attention in academia. While studies on the heat transition highlight the need for a phase-out of natural gas, in academic literature, a gas phase-out is barely discussed, in contrast to the literature, e.g., on the exit from coal or nuclear power in Germany (Fitzgerald et al., 2019). It could be assumed that there is a general belief that the phase-out of gas in the heating of buildings will happen automatically once the new technologies reach a high enough market share. However, as pointed out by Brauers, Braunger, & Jewell (2021), that assumption does not consider the potential lock-in effects of the old technologies, which highlights the need for further research.
Nevertheless, some studies examine the consequences for the gas grid of a decrease in natural gas consumption, e.g., because of high electrification. For instance, Kusch et al. (2012) found that if the share of renewables in the electricity grid increases, that will have consequences on the gas grid. With lower gas demands, they conclude, the economic operation of gas grids will be questionable. In a more recent study, Giehl et al. (2021) modelled the impact of the energy transition on gas distribution networks using different scenarios. The authors highlighted that in most studies examining higher electrification or changes in the heating system, implications for the gas distribution networks are not considered. They found that there will be a declining need for gas distribution networks in all analysed scenarios. In all-electric scenarios, the required network length would decrease substantially, but also in scenarios with a high percentage of synthetic gases in the heating system, the need for gas distribution infrastructure will decrease. The authors also highlight the risk of potential lock-ins or sunk costs due to the assumption of gas as a bridge fuel.

Furthermore, studies focus on the potential role of low-carbon gases in the heating system. As summarised by Jensen et al. (2020), the studies set different foci and utilise different models and approaches, e.g., energy, environmental, and life cycle assessment (e.g., Berglund & Börjesson, 2006; Collet et al., 2017; Hamelin et al., 2014); supply chain and feasibility models (e.g., Bekkering et al., 2013; Jensen et al., 2017); or integrated and holistic energy systems models (e.g., Börjesson & Ahlgren, 2012; Meibom & Karlsson, 2010; Pedersen et al., 2017). Jensen et al. (2020) consider energy system models most useful for examining plausible future energy developments, which they also apply in their study. They find that in general, low-carbon gases, e.g., hydrogen, can be a substitute for natural gas in sustainability transitions, and in Germany,

there is a higher need for substitute gases than, for example, in Scandinavia. However, they also find that when considering early emission reduction targets, electrification, i.e., the use of wind and solar, is favourable over natural and renewable gas. Hydrogen can play a role, especially as a storage medium; however, high costs need to be considered. The high costs of hydrogen were also emphasised by Baldino et al. (2021), that find that heat pumps are more cost-competitive compared to hydrogen in GHG-neutral residential heating. Interestingly, one study by Szabo (2021b) analyses the effects of what the author calls the 'hydrogen energy utopia' (p.91) in the context of the European energy system. The author states that even though the uptake of hydrogen is still in its early stage of development, using the utopia of introducing hydrogen to the gas grid has allowed incumbent natural gas industry actors to capture future markets. This allows them to maintain their capital accumulation practices and impair their renewable competitors.

Furthermore, there are some major uncertainties around the potential, costs, and technical feasibilities of alternative gases in the heating system, as pointed out by Lowes et al. (2020) for the UK context. First, when looking at hydrogen, they point out that carbon reduction potentials of hydrogen are uncertain, especially as green hydrogen will not be unlimitedly available and thus it is likely that other forms of hydrogen might be included. Furthermore, while with green hydrogen, near-zero carbon emissions could be achieved in theory when using renewable and low-carbon electricity, techno-economic analysis suggests that direct electrification would be the economically better option for heat in buildings (e.g., analysed for the UK context by Strbac et al., 2018). Second, there are large cost uncertainties around hydrogen, due to the lack of practical hydrogen conversion projects, all statements about costs of transforming the heating system to include hydrogen are estimated and uncertain (Lowes et al., 2020). In addition, due to the lack of real-world experiences, literature has pointed out that there is substantial technical uncertainty around hydrogen. This refers to, e.g., the technical feasibility of carbon capture and storage potentials (Middleton & Yaw, 2018), the development of appliances to burn hydrogen, the suitability of pipework, and the safety of hydrogen (Lowes & Woodman, 2020). With regards to biogas, Lowes et al. (2020) highlight the differences in carbon intensity depending on the type of bioenergy feedstocks used to produce biogas, as well as the limited availability of suitable biomass resources. Thus, the authors suggest that biogas should play a niche role in the heating system, e, g., to cover peaks in the heat demand.

In line with that, studies focusing on the German heat transition are also cautious about counting on using hydrogen in the heating of buildings, as the availability and potential of hydrogen are too uncertain to make reliable predictions about its potential usage (Hainsch et al., 2020; Prognos et al., 2021; Wachsmuth et al., 2019). Furthermore, studies also agree in the fact that in most cases, electrification options will be more efficient for the heating of buildings, and hydrogen will be needed more urgently in other sectors (Prognos et al., 2021). Thus, considering the current status of knowledge, the studies conclude hydrogen should only be used for the heating of buildings in exceptions (Hainsch et al., 2020; Wachsmuth et al., 2019).

Next, there is a growing number of studies focusing on *specific, alternative heating technologies*, lately especially heat pumps and decarbonised heat networks. Multiple studies highlight the importance of *heat pumps* for the German heat transition (Bernath et al., 2019; Gaur et al., 2019; Hilpert, 2020; Merkel et al., 2017; Sterchele et al., 2017). The studies commonly count on a large roll-out of heat pumps within the coming years, to replace fossil fuel-based heating and thus contribute to reaching the emission reduction goals of the building sector (Bernath et al., 2019; Merkel et al., 2017; Rivoire et al., 2018). For instance, Sterchele et al. (2017) highlight that with increasing carbon reduction targets, the predominance of purely electrically driven heat pumps increases, while gas- and oil-based heating decreases drastically. However, when it comes to the potential of heat pumps, the literature also points out some factors that need to be taken into consideration. First, the share of renewable energies in the electricity mix needs to increase to achieve emission reductions, e.g., when compared to a condensing gas boiler (Bockelmann &

Fisch, 2019; Huchtemann & Müller, 2012; Sterchele et al., 2017). Second, studies point out that the energy efficiency of heat pumps depends on the correct set-up and thus, the choice of the heat source, the most suitable heat exchanger, and the controlling system, as well as the correct planning, installation, and operation of the heat pump are of decisive importance (Bockelmann & Fisch, 2019; Huchtemann & Müller, 2012; Miara et al., 2017). This, according to the authors, highlights the need for proper monitoring and maintenance to ensure maximum efficiency (Bockelmann & Fisch, 2019; Miara et al., 2017). Furthermore, studies have highlighted the differences in the energy efficiency of heat pumps operating in older, un-refurbished buildings and in newly constructed buildings with surface heat distribution (Huchtemann & Müller, 2012; Miara et al., 2017). Huchtemann and Müller (2012), for instance, point out that it is more challenging to achieve good overall performances in existing buildings due to high flow temperatures. In that sense, however, more recent studies have emphasised the improved technical feasibilities as well as increased experience with the installation of heat pumps, making heat pumps suitable for various building types. A study for the UK context, for instance, highlighted that heat pumps can be suitable for various building types, regardless of their age or refurbishment status (Energy Systems Catapult, 2022). And in a project in Germany, it has been demonstrated that making a building suitable for heat pumps and lower flow temperatures does not necessarily mean an excessive building refurbishment, but in most cases, a few targeted measures are enough to operate a heat pump efficiently (Mellwig et al., 2021). Lastly, a main barrier to the diffusion of heat pumps is seen in their higher initial costs compared to other heating technologies (Gaur et al., 2019; Rivoire et al., 2018; Spitalny et al., 2014). However, Gaur et al. (2019) also point out that the initial investment costs will be counterbalanced by lower operational and environmental costs, and Rivoire et al. (2018) highlight that the economic advantage of heat pumps would improve by changing taxation on gas and electricity. Besides, the study by Energy Systems Catapult (2022) states that the heat pumps technology is expected to improve and costs to decline over the next decade, making heat pumps the increasingly obvious choice for customers.

Next, *heat networks* or district heating systems are deemed to be increasingly important for the German heat transition, as highlighted by several authors (Dunkelberg et al., 2020; Fraunhofer IWES/IBP, 2017; Pelda et al., 2021; Triebs et al., 2021). They are especially relevant and economically feasible for cities and high populated areas (Dunkelberg et al., 2020; Persson & Werner, 2011; Weiß et al., 2018). A common challenge emphasised in the literature is the need to decarbonise the heat networks to contribute to emission reduction goals (Popovski et al., 2019; Triebs et al., 2021). Thus, there are a lot of studies focusing on possible decarbonisation pathways for heat networks, exploring, e.g., the potential of solar thermal, waste incineration plants, or heat pumps (Pelda et al., 2020; Popovski et al., 2019; Triebs et al., 2021).

To conclude, with regards to the German energy transition, there is a strong focus on electricity as compared to heat, which – especially together with the large emission reduction potentials in the heat sector – highlights the need for further research on the heat transition. Furthermore, while there is a considerable amount of literature on renewable heating technologies, especially heat pumps, research and practical recommendations concerning a gas exit in the building sector are scarce. Studies examining the implications of the heat transition on the gas grid highlight the decreasing need for gas distribution networks and the risk of carbon lock-ins, which demonstrates the relevance of further research on those risks. Furthermore, the risk of relying on alternative gases in the heat transition has been highlighted.

3.2 Carbon Lock-Ins and Natural Gas

Carbon lock-ins have been defined as a form of path-dependency or inertia to large-scale change because of "mutually reinforcing physical, economic, and social constraints", that increase carbon emissions (Seto et al., 2016, p. 425). In that regard, it has been highlighted that there is

a risk in industrial economies to preserve fossil fuel-based systems despite their known environmental externalities and the apparent existence of alternative pathways including renewable energies (Unruh, 2000). Consequently, renewable energy or renewable technologies do not receive sufficient political support to propagate. This is, as found by Unruh, (2000), also reflected in policy actions: Governments frequently exacerbate carbon lock-ins through subsidy and institutional policy instead of rationally correcting market and policy failures.
Furthermore, it was found that carbon lock-ins pose significant risks to fighting climate change, as they are especially prone to entrenchment considering the long infrastructure lifetimes, large capital costs, and interrelations between the technical and socioeconomic systems (Seto et al., 2016). Furthermore, researchers highlighted that the urgency of addressing climate change exacerbates the danger of even small lock-in risks (Seto et al., 2016). Fisch-Romito et al. (2021) highlight that long-lived capital stocks such as buildings and infrastructure, in particular, pose a challenge because of their long-lasting implications for GHG, which might slow down the decarbonisation of energy systems.

Different kinds of lock-in mechanisms exist. Seto et al. (2016) provide a literature review about the types and causes of carbon lock-ins and identify three main types of lock-ins that are commonly referred to in literature: infrastructural/technological, institutional, and behavioural, all interconnected and mutually reinforcing. This conceptualisation is further explained within the conceptual framework (section 4.3). Besides those three commonly mentioned types of lock-ins, discursive lock-ins have gained attention in relation to energy transition studies. Buschmann and Oels (2019) highlight the value of including discourses in studies on carbon lock-ins. They found that discourses can contribute to the creation and enforcement of carbon lock-ins, as well as trigger change. Key actors dominate certain discourses and can thus influence political action (Bosman et al., 2014). However, the analysis of the influence of discourses on the creation of lock-in mechanisms is still in its early stages, and no studies have been identified that analyse discursive lock-ins related to natural gas in the heat transition.

Focusing directly on the risk of creating *carbon lock-ins connected to natural gas* and natural gas infrastructure, there is a limited number of scientific and grey literature. Studies focusing on this topic only emerged recently, mostly in the field of environmental studies. Most prominently for the German context are two studies, both examining the expansion plans of liquefied natural gas (LNG) import terminals in Germany and discussing lock-ins in relation to that. Brauers, Braunger, & Jewell (2021) take on an energy transition perspective and analyse the material conditions in the techno-economic, socio-technical, and political realms of the German natural gas sector. They highlight the severely overlooked risk of gas lock-ins, especially in terms of contradicting GHG emission reduction targets. Furthermore, the authors conducted an actor analysis to identify the most relevant actors for the German natural gas development. Subsequently, they showed how the lock-in effects and the material conditions around natural gas interact with relevant actors' perceptions and interests. Fitzgerald et al. (2019) focused on gaining an understanding of the underlying dynamics of natural gas support. By analysing actors involved in the discussion around the LNG terminals, the discourses and narratives, as well as their interests and politics, they show that support for natural gas results from pressure from incumbent fossil fuel actors.
In addition, the risk of natural gas carbon lock-ins is emphasised in grey literature, including, for example, reports and statements by NGOs. Besides highlighting the environmental risk of missing carbon reduction targets, the financial risk of lock-ins leading to stranded assets is commonly referred to. A blog post by Agora Energiewende (Saerbeck, 2021) points out the paradox between large investments that are being made into gas infrastructure today, both in gas transmission and distribution networks, and the necessary phase-out of gas to stay in line with Germany's emission reduction targets. A discussion paper by Scientists for Future (Brauers, Braunger, Hoffart, et al., 2021) highlights the risk of the large investments in gas infrastructure

becoming stranded assets. They emphasise that due to the longevity of heating infrastructure, lock-in effects are very likely, which would prevent the expansion of renewable energies, and would lead to Germany failing to fulfil its climate targets. They conclude that a gradual phase-out of natural gas will be necessary. The necessity of a gas phase-out is also emphasised by Schrems et al. (2021), that developed a roadmap for a phase-out of natural gas in the building sector. By focusing on the climate costs of natural gas in the building sector, including methane leakages in the supply chains, they show that the climate costs of natural gas have been insufficiently included in the pricing.

Generally, there seems to be a consensus that a risk to create carbon lock-ins regarding natural gas and natural gas infrastructure exists. Both the risks of missing emission reduction targets as well as the risk of stranded investments are highlighted. Furthermore, different studies mention the possibility of discourses and pressure from incumbent actors causing or reinforcing lock-in effects, which shows the relevance of analysing discourses and narratives. Lastly, even though it is emphasised in the literature that the building sector is prone to the risk of lock-in effects due to the longevity of building infrastructure, there is a gap in the literature focusing on the building sector and the implications of gas lock-ins on emission reduction targets in the heating of buildings.

3.3 Narratives and Discourses around Natural Gas

Looking at the literature on *narratives and discourses around natural gas*, there are studies from different geographical contexts on the topic, including, e.g., North America (Delborne et al., 2020; Noga & Wolbring, 2014; Zanocco et al., 2018), the UK (Cotton et al., 2014; Lowes et al., 2020), Germany (Buschmann & Oels, 2019; Fitzgerald et al., 2019; Schirrmeister, 2014), eastern Europe, e.g. Ukraine and Slovakia (Yakovenko & Mišík, 2020), Russia (Ocelík & Osička, 2014), Israel (Rettig, 2016), and China (Zhou & Qin, 2020). A very common finding across the literature is that the narrative around natural gas has been dominated by the bridge or transition fuel narrative (Delborne et al., 2020; Howarth, 2014; Stephenson et al., 2012; von Hirschhausen et al., 2020). Delborne et al. (2020), for instance, highlight the frequency with which the bridge fuel narrative has been repeated in energy policy debates and media. It has been portrayed as the 'least harmful solution' as compared to coal and oil. Fitzgerald et al. (2019) list some more common discourses and framings surrounding natural gas, for example, portraying it as a more flexible energy source and suitable for storing energy. For LNG, they also find that the narratives of diversification and geopolitical concerns are frequently used by incumbents to justify investment in LNG infrastructure.

However, with increasing insights into the environmental lifecycle emissions of natural gas, the 'bridge to nowhere' narrative emerged as a reaction that demonstrates the hindering effect gas can have on energy transitions (Delborne et al., 2020). Furthermore, the bridge fuel narrative has been contested by critiques that say that the metaphor can slow down the transition and lead to lock-in effects (Bessi et al., 2021; Howarth, 2014). Stephenson et al. (2012) highlight that the transition fuel label can be used to legitimise carbon-intensive gas development, and argue for a more differentiated discussion about the characteristics of natural gas. Thus, von Hirschhausen et al. (2020), for instance, call for a new narrative of a natural gas exit.

Focusing on the discourse around alternative gases, both Lowes et al. (2020) and Szabo (2021a) demonstrate that incumbent actors penetrate the discourse around alternative gases like biogas and hydrogen to protect their own interests and entrench the fossil fuel-based energy system. By portraying alternative gases as a feasible solution for the energy transition, they try to shift the focus away from the uncertainties around the potential of these alternative gases and detract from the importance of electrification.

To sum up, this section has shed light on some commonly used narratives around natural gas and has demonstrated that it has mainly been portrayed as a bridge fuel within energy transitions. This has increasingly been criticised by other authors that emphasise the negative climate impacts of gas. However, the above-described studies focus on the narratives around natural gas in general. In contrast, a specific analysis of the narratives around the role of natural gas within Germany's heat transition in the building sector is lacking. This poses a research gap.

3.4 Narratives and Discourses in Transition Research

Interpretative, constructivist, and poststructuralist approaches to transition analysis point out the *relevance of including discourses, assumptions, and values in transition research* (Geels & Verhees, 2011; Köhler et al., 2019; Sovacool & Hess, 2017). The application of interpretive research designs, such as narrative and discourse analysis, in transition research and the analysis of socio-technical systems has increased significantly over the last decade (Rosenbloom et al., 2016; Simoens et al., 2022). The importance of including narratives in transition theory has been highlighted, as people's understanding and perceptions of energy transitions cannot only be formed by communicating facts about technological and environmental issues only but need the evolution of big public narratives as well (Roberts, 2017). This is because narratives and discourses are deeply symbolic and emotional and rooted in history, culture, and people's experiences (Roberts, 2017). Thus, it has also been emphasised that including narrative and discourse analysis allows for more politically sensitive transitions (Rosenbloom et al., 2016; Simoens et al., 2022). Furthermore, analysing discourses can also help to open the 'black box' about preferred strategies to achieve a certain transition outcome. As demonstrated by Munoz et al. (2014), even if the overarching discourse of actors in the system is the same, actors can support different strategies to achieve the desired outcome.

Authors have researched the discourse-transition intersection with different perspectives. Some authors emphasise the importance of narratives and discourses to accelerate change. Roberts (2017) finds that negative storylines can play an important role in undermining dominant socio-technical regimes. Kern (2011), building on a discursive-institutionalist perspective, analyses how discourses, interests, and institutional contexts shape system innovations and finds that change occurs when new discourses challenge existing institutions. Furthermore, Geels and Verhees (2011) highlight the importance of framing in innovation journeys to legitimise technological developments. Shifting the focus to niche strategies, Smith and Raven (2012) conclude that narratives can be a key political strategy to empower niche-derived institutional reforms. On the other hand, authors highlight the power of narratives and discourses to help incumbent actors defend their regime (Pesch, 2015), use their powerful discourses to align the transition to their interests (Bosman et al., 2014) and limit the diffusion of innovations (Smink et al., 2015). Interestingly, one study by Lowes et al. (2020) examines the influence of incumbent discourse coalitions on the transformation of the heating system in the UK. They find that there is a strong pro-gas discourse coalition that defends the threat of electrification by promoting a decarbonisation pathway based on replacement gases, despite the uncertainty around their potential. Furthermore, the authors highlight that due to the capacity the incumbent actors have to promote their storyline, there is a risk of delay in policy development at a time when determined action would be needed to achieve rapid decarbonisation.

To sum up, this section has demonstrated the importance and relevance of analysing discourses and narratives in policy processes and energy transitions. They are an important part in influencing the perception of actors of policy problems as well as in shaping political action. Furthermore, it has been demonstrated that narratives and discourses can play a part both in helping incumbent actors defend their regime and hinder change, and thus promote lock-in effects, as well as accelerating innovation and change.
Despite the demonstrated relevance, there is a lack of studies taking on a constructivist or

interpretative approach to analysing Germany's heat transition in the building sector, e.g., by scrutinising the role of narratives and discourses. This poses a substantial research gap.

3.5 Need for Further Research

This review has pointed out the need for further research on the German heat transition. So far, more attention has been given to the electricity sector, despite the importance of the decarbonisation of the heating of buildings. As natural gas is responsible for heating half of Germany's buildings, there is a particular interest in a more thorough analysis of that energy source. While the potential of renewable heating technologies, especially heat pumps, has been shown, it has been demonstrated that it is crucial to not only focus on the promotion of renewable technologies but also to create an understanding of how old technologies, like natural gas-based heating, can be phased out. Nevertheless, studies focusing on a gas phase-out are scarce, which demonstrates the need for further research. Furthermore, the risk of carbon lock-ins regarding natural gas has been highlighted, both concerning emission reduction targets and stranded investments. However, there is a gap of knowledge about where the ongoing support for natural gas in Germany's heating system comes from, despite the knowledge of the risk of carbon lock-ins. Further research is needed to understand the underlying dynamics of the heat transition and the support for natural gas.

Both the literature on energy transitions as well as on carbon lock-ins emphasise the relevance of discourses and narratives in the policy process. They are an important part of shaping political action and influencing the perception of actors of policy problems. Furthermore, narratives and discourses can play a part both in helping incumbent actors defend their regime and hinder change, and thus create or reinforce lock-in effects, as well as accelerating innovation and change. Nevertheless, while the influence of narratives and discourses on energy transitions as well as on the creation of lock-ins has been shown, there is a lack of studies taking on a constructivist or interpretative approach to analysing Germany's heat transition in the building sector, e.g., by scrutinising the role of narratives and discourses. Thus, there is a gap of knowledge concerning the narratives and discourses about the role of natural gas in Germany's heat transition in the building sector and how they shape the transition and potentially create or reinforce lock-ins. Filling this research gap will be especially relevant as the building sector is prone to the risk of lock-in effects due to the longevity of building infrastructure. This is also important for the fulfilment of the emission reduction targets in the building sector. Therefore, further research that takes on a constructivist or interpretative approach to analysing Germany's heat transition and sheds light on common narratives and discourses concerning natural gas allows generating insights on how to accelerate the German heat transition.

Lastly, the implications of the Russian war on Ukraine impact the discussions around natural gas and the energy system in Germany. There is a substantial need for further research that takes those consequences into account, as the developments have the potential to cause considerable changes in the energy system in Germany.

4 Conceptual Framework: Implications of Discourses and Narratives on the Heat Transition and Lock-Ins

This chapter illustrates the conceptual framework that was developed and used as a guidance for data collection and analysis as well as the discussion of findings in the study at hand. The main purpose of the conceptual framework was to provide a way of understanding the interlinkages between energy transitions, more specifically the German heat transition in the building sector, the mechanism of lock-in creation, and the role of discourses and narratives. The framework builds on several concepts and theories that are outlined in the following sections.

4.1 Multi-Level Perspective

The multi-level perspective (MLP) is a prominent example of transition theory, incorporating the concepts of socio-technical landscapes, a socio-technical regime, as well as a niche and thus focusing on explaining the development of socio-technical systems (Geels, 2002). A socio-technical system, such as energy, refers to the interlinkages and interactions between the socio system (actors and their practices and institutions) and the technical system (material artefacts such as energy infrastructure) (Simoens et al., 2022).

The MLP, in general, suggests that transition occurs through interactions among the three levels: the niche, the regime, and the landscape (Sovacool & Hess, 2017). Niches are defined as the place where novelties emerge, which are initially unstable and supported by just a small network of dedicated actors (Geels, 2002). The socio-technical regime refers to shared cognitive routines and aligned activities of actors involved in the system that explain patterned technological developments along 'technological trajectories' (Geels & Schot, 2007). Those technological trajectories emerge because actors involved in the system, both technologically such as engineers, but also socially such as policymakers, users, and special-interest groups, generally align their acting and decision-making along with the pre-established regimes (Geels & Schot, 2007). Third, the landscape refers to the broader environment beyond the direct influence of regime and niche actors (e.g., cultural patterns or macroeconomics). The landscape usually takes a long time to change. Finally, (socio-technical) transitions occur as an "outcome of linkages between developments at multiple levels" (Geels, 2002, p. 1262). This can be stimulated by interactions initiated at all three levels: (a) Niche-innovations can, through learning processes, support from powerful actors, or improvements of the niche innovation, build up internal momentum; (b) changes at the landscape level, stimulated e.g., though external events like natural disasters, can put pressure on the regime; and (c), windows of opportunity can emerge at the regime level if the regime gets destabilised, e.g., through sudden changes in the landscape or tensions in the regime (Geels & Schot, 2007).

4.2 Narratives and Discourses

Narratives are used to illustrate complex technical constellations and interrelationships and typically include both a problem diagnosis as well as a recommendation for action (Ahmels et al., 2021). They can be understood as social constructions, conveyed as storylines that people use to make sense of reality (Leipold et al., 2019; Libertson, 2021; Patterson & Monroe, 1998). Thus, an underlying assumption in line with the constructivist worldview is that there is no universal reality and truth, but that humans construct meanings and reality, expressed in narratives (McComas & Shanahan, 1999). Hence, narratives express not only facts but also the context and how these facts should be understood (Libertson, 2021). Typically, narratives entail simplifications of complex matters, used to guide and enable actors to make decisions when being confronted with complex and uncertain situations (Hermwille, 2016; Libertson, 2021; Mohan & Topp, 2018). Furthermore, narratives entail a certain value judgement and express

what is desirable within a society, contributing to the maintenance of a certain value system (Ballo, 2015; McComas & Shanahan, 1999; Patterson & Monroe, 1998).

Actors, networks, and institutions typically create and promote certain narratives, based on their basic goals and patterns of arguments within their respective socio-technical regimes (Hermwille, 2016; Leach et al., 2010). The narratives entail particular framings and goals and suggest and justify certain actions and strategies, thus functioning as a guide for action for the regime actors (R. Byrne et al., 2012; Leach et al., 2010). In that sense, narratives can *shape and define certain pathways and steer political action* if they become manifested in and by institutional and political processes, while other narratives remain marginalised. (Leach et al., 2010). Narratives can have a strong influence on policy debate and a clear purpose for policy change (Leipprand et al., 2017a; Mohan & Topp, 2018). They can foster a shared vision and call for action and certain policy outcomes, and thus, for example, legitimise certain investments or promote certain technological solutions (Libertson, 2021). In that sense, narratives can also contribute to the creation of lock-ins (Ampe et al., 2020; Libertson, 2021; Mohan & Topp, 2018).

Closely connected to the concept or narratives are *discourses*. Discourses can be defined as an "ensemble of ideas, concepts, and categorizations that are produced reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer, 1995, p. 44). Discourses and narratives share the assumption that humans construct social realities and interpret their meaning (Hermwille, 2016; Leipprand et al., 2017). Furthermore, both see linguistic framing of policy problems and solutions as an important part of influencing the perception of actors of such, as well as in shaping political action (Bosman et al., 2014; Leipprand et al., 2017). Accordingly, certain discourses are promoted by different groups of actors (Leipprand et al., 2017). Actors who share a common discourse or a social construct, in general, can be grouped into what Hajer (1995) calls 'discourse coalitions'. Those discourse coalitions play an important role in the policy process, as actors try to impose their view of reality on others, through debate, persuasion, but also through the exercise of power (Hajer, 1995).
In understanding the relationship between discourses and narratives, this study follows the interpretation of Urhammer and Røpke (2013) and Leipprand et al. (2017a), that narratives are embedded in discourses and are a type of materialisation of a certain discourse. Thus, revealing prominent narratives sheds light on the existing discourse.

Important when looking at discourses (or narratives) in the policy process is the concept of *discursive agency*. The concept of agency is closely linked to the concepts of legitimacy, representation, and responsibility and is considered to be essential in the study of policy change (Leipold & Winkel, 2017). Discursive agency, then, can be defined as "an actor's ability to make him/herself a relevant agent in a particular discourse by constantly making choices about whether, where, when, and how to identify with a particular subject position in specific storylines within this discourse" (Leipold & Winkel, 2017, p. 524). As policy discourses are typically characterised by multiple narratives by various actors of the system competing for the truth, policymaking is essentially about making one's own narrative heard, which depends on the actors' agency (Leipold & Winkel, 2016). Different strategies exist for how actors can increase their agency, one of which is building coalitions (Leipold & Winkel, 2017).

4.3 Conceptualisation of Lock-In Mechanisms

There are different types of lock-in mechanisms. Most important for this study, focusing on the role of narratives and discourses, are discursive lock-ins, that in turn also can add to the creation of institutional, behavioural, and infrastructural lock-ins.

Discursive lock-ins in the context of energy transitions emerge if a certain discourse reinforces the stabilisation of a socio-technical system and thus prevents the transformation away from a fossil fuel-based system. Relevant to understanding discursive lock-ins is the concept of 'mental maps' that guide actors' decision-making processes. According to Pierson (2000), "understandings of the political world should themselves be seen as susceptible to path dependence … The development of basic social understandings involves high start-up costs and learning effects; they are frequently shared with other social actors in ways that create network effects and adaptive expectations. The need to employ mental maps induces increasing returns" (Pierson, 2000, p. 260). In other words, as following a given discourse on a topic requires less effort than forming an understanding oneself, societal and political actors tend to follow such discourses provided by dominant actors. This leads to discourses of dominant actors being reproduced more, as they have the means and credibility to reach and influence people's opinions and actions. Thus, a discursive lock-in can be understood as a mechanism when a certain discourse constitutes and justifies the fossil fuel technologies, institutions, and behaviours of the status quo, and prevents transformation.

Different types of discursive lock-ins have been described by Simoens et al. (2022) in relation to socio-technical systems and the MLP. The authors show how three discursive lock-ins can exist that stabilise or reinforce socio-technical systems. At the meta level, unchallenged values and assumptions of the meta discourses can lead to a discursive lock-in. They are powerful, as discourses reproducing the same perception of reality as the meta discourse will unlikely be questioned and often be perceived as the best way within a socio-technical system. The second type of discursive lock-in stems from the incumbents' strong discursive agency at the regime level. This strong agency allows them to reproduce the institutionalised discourse more successfully than non-incumbents with a weaker agency. Lastly, at the niche level, a discursive lock-in can emerge if the alternative discourse is either too radical or too close to the institutionalised discourse: Radical discourses, on the one hand, entail the risk of not being reproduced. Marginal discourses, i.e., discourses close to the institutionalised discourse, on the other hand, hold the risk of losing their transformational power when they align too closely with the dominant discourse.

To overcome those lock-ins, Simoens et al. (2022) identify three pathways: A disruptive discursive change refers to a transformation based on exogenous events that change the values and assumptions at the meta level. A dynamic discursive change stems from within the system, e.g., when alternative discourses are made attractive for incumbent actors and thus destabilise the institutionalised discourse. Lastly, cross-sectoral discursive change can occur between related socio-technical systems (e.g., energy and mobility), when changes in one system may create a change in the related system.

Building on the understanding that discourses are reproduced in social practices, dominant discourses can also shape the technologies, institutions, and behaviours of the status quo (Buschmann & Oels, 2019). In that sense, discourses can reinforce or create institutional, behavioural, and infrastructural lock-ins.

Infrastructural or technological lock-ins refer to lock-ins created by physical infrastructure (Seto et al., 2016). This includes for example buildings, but also fossil fuel–supporting infrastructures such as pipelines or refineries, affecting energy demand for decades after their construction. Due to the longevity of such infrastructure, changes to those carbon-intense pathways later might be costly or difficult, which highlights the importance of early decisions and initial conditions (Fisch-Romito et al., 2021; Seto et al., 2016). Furthermore, a self-reinforcing mechanism to resist change exists between infrastructure (such as buildings) and supporting infrastructure (such as gas pipelines), as the supporting infrastructure usually cannot be readily used by other systems as they are built for a specific task (such as transporting gas). Typically, the large infrastructure is also connected with high initial investment costs, which is why the risk of stranded assets is

commonly mentioned (Fisch-Romito et al., 2021; Seto et al., 2016). Interestingly, Erickson et al. (2015) performed an analysis assessing the proneness of specific energy-consuming assets in the buildings, industry, power, and transport sectors and found that besides coal-fired power plants, gas power plans lock in a big share of carbon emissions.

Institutional lock-ins are based on the premise that institutional choices at a given point in time have a significant impact on later choices (Pierson, 2000; Seto et al., 2016). Political, social, and economic actors involved in the system tend to reinforce a status quo trajectory that favours their interests and provides them with certain benefits. To achieve that, they intentionally and coordinated engage in efforts to impact institutional norms, rules, and constraints in their interest and defend those against a new status quo. Usually, changes in the institutional system do not happen randomly but are the result of intentional choice or other factors, e.g., exogenous shocks (Pierson, 2000; Seto et al., 2016).

Behavioural lock-ins refer to the persistence of carbon-intensive behaviours (Seto et al., 2016). This includes decision-making at an individual level, as well as social structures. On an individual level, based on models of psychological decision-making, scholars describe the impact of habits (when single, intentional choices become non-calculated and self-reinforcing) on the creation of lock-ins. However, also societal structures and context influence behaviour, norms, and social processes that need to be considered (Seto et al., 2016).

4.4 Conceptual Framework

The framework used in this study has been adapted from Simoens et al.'s (2022), who have linked discourses in socio-technical systems with the risk of lock-in creation and show that discourses can help incumbents to stabilise their regime. They describe different types of discourses relating to the different levels of socio-technical systems: On the landscape level, there is a 'meta discourse', which is not specific to one actor, but is more general and can be understood as a dominant construct of meaning in society. To radically shift the meta discourse, which relies on deep-rooted values and assumptions, changes in the ideological context are needed. Second, there are institutionalised discourses at the regime level, represented by dominant narratives reproduced by a coalition of incumbent actors with strong discursive agency (see e.g., Leipold & Winkel, 2016). They relate to established practices, infrastructure and technologies, and institutions. However, the institutionalised discourse can change over time, e.g., due to discursive struggles with an alternative discourse (see e.g., Kaufmann & Wiering, 2022). Lastly, there are alternative discourses at the niche level. They are represented by typically weak discursive agents and may be radical discourses representing a completely new innovation or marginal discourses not disrupting the dominant discourse, as well as everything in between (see e.g., Smith & Raven, 2012). The alternative discourses do not hold power in themselves yet, and the likelihood of their success does depend not only on their legitimacy and attractiveness but also on the strength of the agents reproducing them.

However, the framework has been slightly adapted to better fit the focus of the study at hand, and thus the concepts of narratives and discourse coalitions, as described in the previous sections, have been incorporated. Figure 4-1 illustrates the conceptual framework.

First, the framework shows the *socio-technical system* which constitutes the system boundaries of the study at hand: the heat transition of the building sector in Germany. Furthermore, the three levels of the socio-technical system, as described by the MLP (Geels, 2002; Geels & Schot, 2007) are illustrated. The *landscape level* represents the broader environment, e.g., cultural patterns or macroeconomic developments. The *regime level* represents the shared cognitive routines and aligned activities of actors involved in the system that explain patterned technological development. Material artefacts, such as infrastructure, behaviours, and institutions (in most of

the literature on socio-technical regimes loosely defined as "the formal and informal rules within a society as well as the relevant organizations which embody these rules" (Andrews-Speed, 2016, p. 217)) are strongly influenced by the regime actors. Lastly, the *niche level* is the place where novelties emerge.

Second, the *narratives and discourses* at the three levels are shown. The framework illustrates that narratives are embedded in a certain overall discourse, i.e., are a part of a discourse (Leipprand et al., 2017; Urhammer & Røpke, 2013). As scholars have highlighted that revealing prominent narratives sheds light on the broader discourse, both narratives and discourses are shown in the framework and subsequently also included in the analysis. Furthermore, the framework builds on the assumption that narratives and discourses play an important role in policy processes, by influencing the perception of actors in the system, and shaping political action (Bosman et al., 2014; Patterson & Monroe, 1998; Shanahan et al., 2018). *Discourse coalitions* are also illustrated, as certain discourses are commonly supported by coalitions of actors who join their forces to fight for the success of 'their' discourse in the socio-technical system (Hajer, 1995).
In addition, the framework differentiates between the discourses at the three levels of the socio-technical system: the meta discourse at the landscape level, the institutionalised discourse at the regime level, and the alternative discourse at the niche level (Simoens et al., 2022). The *meta discourse* is the general construct of meaning in society, embedded in the general values, assumptions, and practices at the landscape level. The *institutionalised discourses* at the regime level are represented by dominant narratives reproduced by a coalition of incumbent actors with strong discursive agency. Third, the *alternative discourses* at the niche level, are represented by typically weak discursive agents and may be radical discourses representing a completely new innovation or marginal discourses not disrupting the dominant discourse, as well as everything in between.

In line with the three levels of discourses, *three different types of discursive lock-ins* exist. At the meta level, unchallenged values and assumptions of the meta-discourses can lead to a discursive lock-in. At the regime level, regime actors, that typically have a strong discursive agency, reproduce the institutionalised discourse, which leads to the second type of discursive lock-in. Lastly, at the niche level, a discursive lock-in can also emerge from the divergence between radical discourses, which entail the risk of not being reproduced, and marginal discourses, which hold the risk of losing their transformational power when they align too closely with the dominant discourse. The discourses and discursive lock-ins can also have an impact on other types of lock-ins that can emerge from the regime level: behavioural, institutional, and infrastructural carbon lock-in effects.

To overcome the lock-ins and stimulate change, the framework demonstrates two pathways. First, a *disruptive discursive change* refers to a transformation based on exogenous events that change the values and assumptions at the meta level. Second, a *dynamic discursive change* stems from within the system, e.g., when alternative narratives are made attractive for incumbent actors and thus destabilise the institutionalised discourse.

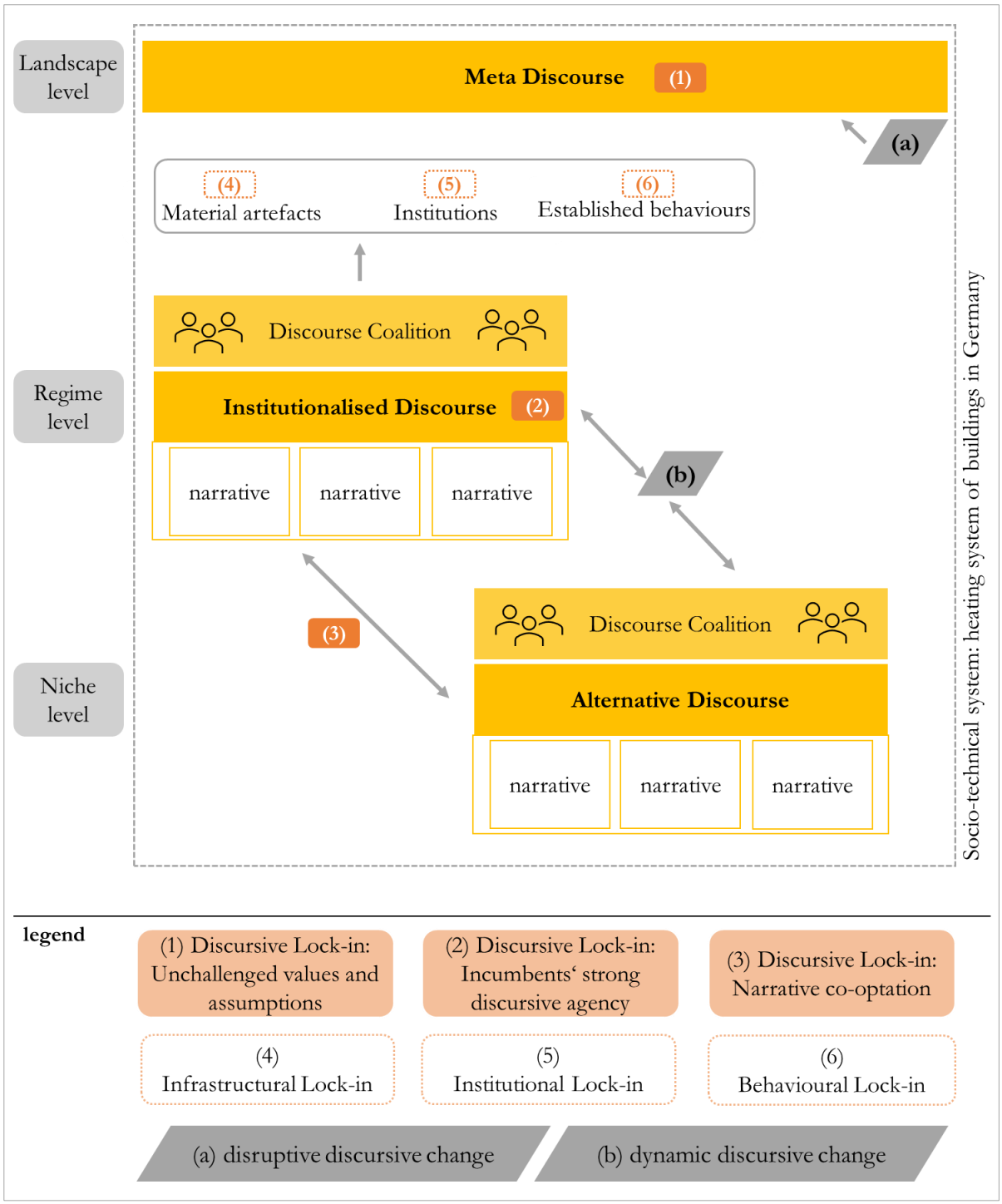

Figure 4-1. Conceptual framework
Source: Own presentation, adapted from Simoens et al. (2022), based on Simoens et al. (2022); Hajer (1993); Leipprand et al. (2017); and Seto et al. (2016)

5 Research Design, Materials, and Methods

The research design of this thesis is presented in this chapter. After some general information about the research design, details about data collection and data analysis are given.

5.1 Research Design: Thematising Narratives and Discourses

This thesis follows a qualitative research approach, as it was deemed most suitable to capture the different actors' perceptions as well as narratives and discourses (Creswell & Creswell, 2017). In qualitative research, the researcher takes on a central role in the research process, and thus it needs to be acknowledged that data collection, analysis, and interpretation might be influenced by the researcher's worldview, previous knowledge, and values (Creswell & Creswell, 2017). The worldview applied in this thesis can best be placed in the sphere of constructivism, because of the emphasis that is placed on capturing the complexity of different actors' views and the understanding that human beings "construct meanings as they engage with the world they are interpreting" (Creswell & Creswell, 2017, p. 46).

A dual approach to data collection was applied, including both semi-structured interviews (see section 5.2.2) as well as documents published by various actors (see section 5.2.3). To identify which actors to interview and which documents to include in the analysis, relevant actors involved in the discussion had to be identified first (see section 5.2.1). A thematic analysis was performed to capture and analyse the actor's narratives and discourses in the collected data sets (see section 5.2.4). The identified themes were analysed building on the conceptual framework of the study and based on that, conclusions were formed.

The conceptual framework as described in the previous chapter provided guidance for data collection and analysis. As the relevance of narratives and discourses on energy transitions and lock-in creation has been highlighted, data collection mainly focused on capturing common narratives and identifying discourses. The conceptual framework helped to specify the identified narratives and discourses and link them to the respective level in the socio-technical system of the German heating of buildings. Furthermore, the framework helped the data analysis to understand how discursive lock-in mechanisms can lead to the stabilisation of a socio-technical regime, or how discursive change can accelerate the transition.

5.2 Data Collection and Analysis

5.2.1 Actor Selection

In the first step, it was crucial to identify relevant actors that are involved in the discussion around the role of natural gas in Germany's building sector, to subsequently include them in the analysis of documents and semi-structured interviews. The actor selection was conducted in two stages.

First, other studies with a similar research focus were consulted to identify the actors that were analysed. For instance, Leipprand (2017) explored the discourses and narratives of actors involved in the German energy transition and provide a list of relevant actors. Furthermore, Fitzgerald et al. (2019) analysed the role of actors and their networks in the political processes surrounding natural gas support and identified a list of influential actors. Brauers, Braunger, & Jewell (2021) also analysed the role of natural gas in Germany and, based on actor analysis, identified relevant actors involved in the discussion. Furthermore, research on advocacy coalitions gave some indications about the actors involved in the German energy system (Gründinger, 2015; Joas et al., 2016). Advocacy coalitions, for the study at hand, are understood as being closely connected to the concept of discourse coalitions, and thus provided some valuable information about which actors are generally involved in Germany's energy system, but

also some indications about which actors are likely to form a discourse coalition. Advocacy coalitions are formed based on the shared belief system of actors involved (i.e., "a set of basic values, causal assumptions, and problem perceptions" (Sabatier, 1988, p. 139)) (Sabatier & Weible, 2014; Schlager, 1995). The coalitions seek to convert their beliefs into policy strategies to achieve a certain policy outcome, and thus, different coalitions also compete for influence on policy outcomes (Jenkins-Smith et al., 2014; Weible et al., 2011). Advocacy coalitions have been linked to the concept of narratives and discourses, as coalitions tend to use similar narratives and discourses (Bulkeley, 2000; McBeth et al., 2014; Rennkamp et al., 2017; Shanahan et al., 2011). For the German context, Leipprand et al. (2017) and Maatsch (2013) identified two coalitions involved in the German energy debate: A proactive coalition advocates for fundamental changes in the energy system to combat climate change, but also highlights the economic benefits of that transition like job creation. A reactive coalition, in contrast, supports an energy mix including fossil and nuclear energy which is argued to be needed for an affordable and secure energy supply, doubts the economic potential of renewable energies, and shows scepticism towards energy transition policies.

Second, desktop research was conducted to identify which of those actors that were identified in the first step are currently involved in the ongoing debate about natural gas in the building sector. For this purpose, a Google search was performed, searching for the actor in combination with keywords including 'natural gas', 'heat transition', 'buildings', and webpages of the actors as well as newspaper articles were consulted to understand who contributes to the debate. This resulted in the identification of the following actors or actor groups (see Figure 5-1).

Figure 5-1. Actors involved in Germany's heat transition in the building sector and the discussion around gas Source: Own presentation

However, it needs to be acknowledged that this list of identified actors is not complete and could be extended to include a wider range of actors. While the above-mentioned actors are the ones that have been found to be most prominent in the debate about natural gas in the building sector, this identification is only based on the research that has been conducted for the study at hand, and thus is also only valid within that scope.

5.2.2 Semi-Structured Interviews

Semi-structured interviews were conducted to capture the actors' views and narratives concerning the role of natural gas in the heating of buildings in Germany. Interviews were

especially useful for this thesis to capture views and perspectives that might not be included in published documents. Furthermore, it allowed for asking precise questions and controlling the line of questioning. However, some limitations need to be considered (Creswell & Creswell, 2017). First, interviews only provide indirect information filtered through the view of interviewees, and potentially those views do not reflect the views of the broader actor group. Second, interviews do not take place in a natural setting and thus provide information only in a designated place and time. Third, the interviewee's responses could be biased by the researcher's presence. Therefore, documents were analysed in addition to the interviews, to counterbalance some of the limitations.

For the study at hand, semi-structured interviews were chosen because of the flexibility they allow and the exploratory approach they entail (Horton et al., 2004). Semi-structured interviews usually include a blend of closed- and open-ended questions and allow the researcher to follow up on certain answers ('probes') to gain more depth on a topic (Adams, 2015). Thus, the conversation can meander around topics the researcher wants to touch upon, rather than following a strict procedure (Roulston & Choi, 2018). Following the RQs and the conceptual framework, the first aim of the interviews was to gain an understanding of the narratives and discourses used by the actors to describe the heat transition in the building sector as well as the role of natural gas in that transition. Second, it was attempted to gain insights into what implications the actors saw based on their stated priorities for the heat transition and natural gas. Thus, questions were asked focusing on political measures that were deemed necessary, as well as the risk of lock-in creation. While the interview guide was slightly adapted for each interview, the general interview guide is provided in Appendix A: Interview Guide.

The interviewees were recruited via email and linked-in, as well as phone calls. Furthermore, as the interviews proceeded, the interviewees were able to provide further contacts (snowballing). Due to the ongoing pandemic and the different locations of the actors across Germany, the interviews were held via online video platforms. If the consent of the interviewees was given, the interviews were recorded, otherwise, notes were taken. The information sheet about participation and data handling can be found in Appendix B: Interview Consent Form.

The interviews usually had a length of 30-60 minutes. In total, 16 interviews were performed, and actors of all relevant actor groups were covered by the interview. While, due to data protection agreements, the names of the actors and organisations are not disclosed, an overview of the conducted interviews can be found in Appendix C: Overview of Conducted Interviews.

5.2.3 Document Review

To complement the interviews, documents were reviewed as well, to provide a more solid basis for analysis. Including documents in the analysis has the advantage of obtaining the language and choice of wording of the actors, as well as representing data that the actors have given attention to (Creswell & Creswell, 2017). On the other hand, it might be difficult to capture the views of all relevant stakeholders, as some might not publish reports or articles.

Documents for a document review can include a wide range of documents (Creswell & Creswell, 2017). For this thesis, the approach for selecting documents was the following:

Building on the interviews and the list of identified relevant actors, documents were selected that covered the actor's view on the role of natural gas in Germany's building sector, by looking for keywords including 'natural gas', 'heat transition', 'buildings', etc. When available, official reports were chosen, if not, also blog posts or the actors' official websites were included. Only sources published by the actors themselves were analysed, and thus, e.g., newspaper articles or other media coverage was excluded, as it was deemed most suitable to identify the narratives

used by the actors. Furthermore, only documents were included that had an agenda for (political) action, as this was considered relevant to ensure that the narratives and discourses used also were intended to impact the transition. Lastly, it was made sure that after having finalised the list of interviews, the documents and interviews together represented a balanced picture of the views of all actor groups. The list of analysed documents can be found in Appendix D: Overview of Documents Reviewed.

5.2.4 Data Analysis

The interview and document data were analysed based on the approach of (reflexive) thematic analysis.

Thematic analysis is a common approach in qualitative research and is a suitable tool to identify narratives and discourses (Bryman, 2012; Lainson et al., 2019). Generally, the thematic analysis seeks to identify "patterns ('themes') across qualitative datasets" (Braun et al., 2019, p. 844), which means going beyond simply describing data to interpreting it (Mackieson et al., 2019). Scholars commonly distinguish between two or three types of thematic analysis that vary in their assumptions and methods (Braun et al., 2019; Willig & Rogers, 2017). *Coding reliability approaches* are deductive – codes and a coding frame are developed and defined at the beginning of the research process and allow the researcher to categorise the data into those predetermined codes (Willig & Rogers, 2017). Often relying on multiple, independent coders, the goal is to produce 'accurate' and 'reliable' codes within data to arrive at a singular, 'correct' analysis of the data (Braun & Clarke, 2021; Mackieson et al., 2019). In contrast, *reflexive thematic analysis* is mostly inductive in nature, themes and codes are conceptualised and developed while engaging with the material, and the coding process is organic and iterative (Braun et al., 2019). The subjectivity of the researcher is acknowledged and thus the aim of the research process is not to create reliable and replicable data, but rather to provide a compelling interpretation (Braun et al., 2019; D. Byrne, 2021). Nevertheless, for instance, Braun and Clarke (2021) argue that it is also possible to employ a more deductive approach with reflexive thematic analysis and use existing theory and research to provide a lens to analyse the data (Braun & Clarke, 2021). Thirdly, *codebook thematic analysis* is often seen as a more pragmatic attempt and a bridge between the two beforementioned approaches. Researchers applying this approach usually use some form of a coding framework developed deductively based on previous research, however, new codes and themes can be defined inductively throughout the analytical process and the engagement with the data (Braun et al., 2019). While data reliability and generalisability and consensus between coders are not usually seen as measures of quality, they can still be included in codebook approaches (Braun & Clarke, 2021).
The study at hand sits at the borderline between reflexive and codebook thematic analysis: The most emphasis was given to capturing the narratives and discourses of the actors in the analysed material, which required a mostly inductive approach following reflexive thematic analysis. Themes, or narratives, were the outcome of the research rather than the predetermined lens for analysis. Furthermore, it is acknowledged that data reliability and generalisability cannot, or only to a limited extent, be achieved since the context of the research impacts data collection and analysis. However, as the goal of the study at hand was to also assess what impacts the identified themes (narratives) have on political processes and outcomes, to some extent a pre-defined framework gave some guidance and a frame into which the narratives were analysed.

After preparing the data by transcribing the interviews, the first step was to create a general understanding of the generated data by familiarising oneself with the collected material (Braun et al., 2019; D. Byrne, 2021). Subsequently, the material was engaged with in more detail and codes were generated inductively. This preliminary set of codes was applied to the collected data, however, throughout the process, new codes could be added as they emerged, as the coding process is iterative and flexible (Willig & Rogers, 2017). The third step was what is

labelled as 'theme development' in reflexive thematic analysis, where the codes are assigned to overall themes (Vaismoradi et al., 2013). Subsequently, those themes were reviewed and redefined to develop a final thematic map (Braun et al., 2019). For this study, most of the themes were equal to what has been defined to be a narrative – thus, the thematic analysis resulted in the identification of the most prominent narratives. These narratives could be assigned to an overall discourse they feed into. Based on the findings, actors were grouped into discourse coalitions. Thus, the analysis resulted in the identification of narratives and discourses as well as the actors that make use of those discourses. In addition, the thematic analysis resulted in themes that were of a more general nature and not part of a narrative, but still relevant to the findings. The final coding framework can be found in Appendix E: Coding Framework.

To support the coding process, NVivo, a computer-assisted qualitative data analysis software, was used. All interview and document data were uploaded into NVivo and coded using the software. This allowed for an easier, more flexible, and more structured analysis of the data and facilitated the identification of the most important themes. While the use of the software is useful for qualitative researchers in managing data sets, its limitations need to be recognised (Heracleous & Fernandes, 2019). Computer-assisted data analysis software is not intended or suitable for substituting the analyst's capacities and rational capabilities and thus the researcher remains the main generator of insights and analysis (García-Horta & Guerra-Ramos, 2009).

6 Findings and Analysis

This chapter presents the findings of the research. Therein, this chapter seeks to answer the posed RQs for this thesis, structured according to the employed framework. The findings and analysis are presented in an intertwined manner, as the identification and allocation of interview and document data into narratives and discourses, as they are presented in this chapter, already entail analytical aspects. Figure 6-1 summarises and visualises the main findings. While the following paragraph summarises the main findings as illustrated in the framework (see words in italics for elements of the framework), the individual parts of the framework will be explained in more detail in the following sections.

First, answering RQ1, the most prominent narratives used to describe the role and significance of natural gas in the current discussion about Germany's heat transition in the building sector are described. To answer RQ1a, these narratives have been allocated to a bigger discourse the narratives feed into. The findings show that two big discourses and thus two discourse coalitions exist in the current discussion around natural gas in Germany's heating system of buildings: one (in simplified terms) pro-gas discourse (*gas discourse coalition*, GDC) at the regime level and one contra-gas (*electrification discourse coalition*, EDC) at the niche level. The EDC pushes for a fast exit from natural gas and advocates for solutions that are currently still at the niche level (heat pumps and decarbonised heat networks). Their narratives are strongly based on *climate change*, *energy security and resilience*, and *lock-ins and stranded assets*. Representatives of the EDC include *environmental NGOs, environmental research institutes and think tanks, the renewable heating technologies industry*, as well as some *state actors*. The GDC, in contrast, is advocating for keeping gas in the heating of buildings – both natural gas, but increasingly promoting a vision for the expansion of low-carbon gas, especially hydrogen. Their narratives are centred around the *bridge fuel vision, free competition and innovation,* as well as *social aspects, convenience, and high acceptance*. The coalition is made of *gas industry associations, network operators, energy suppliers*, and some *state actors*. Interestingly, a *common narrative* of the two coalitions can be identified and has been allocated to the meta discourse: Both coalitions strongly base their arguments on the fulfilment of climate goals and reaching climate neutrality by 2045.

Second, RQ2 is centred around analysing the likely implications of the narratives and discourses regarding the role of natural gas for the German heat transition in the building sector, especially considering lock-in effects. A *discursive lock-in* at the regime level has been identified, which allowed the regime actors to portray gas as the central solution for the heat transition. In turn, this has consequences on *material artefacts* (infrastructural lock-in), *behaviours* (behavioural lock-in), and *institutions* (institutional lock-in). Thus, there is the risk that these lock-ins slow down the heat transition and climate targets will be missed. However, two current developments can be seen as 'windows of opportunity' for the heat transition that could lead to (discursive) changes: First, the *Russian war* on Ukraine has led to a new understanding of energy security and the negative consequences of fossil gas imports, which could lead to more acceptance and willingness in society to contribute to the heat transition. Second, the *increasing competitiveness of heat pumps* leads to a discursive change. Renewable heating options like heat pumps are continuously gaining market share and attention, while at the same, negative consequences of the use of natural gas become more prominent with more research, especially on methane leakages. Thus, there is currently a chance to bring the heat transition to the next level.

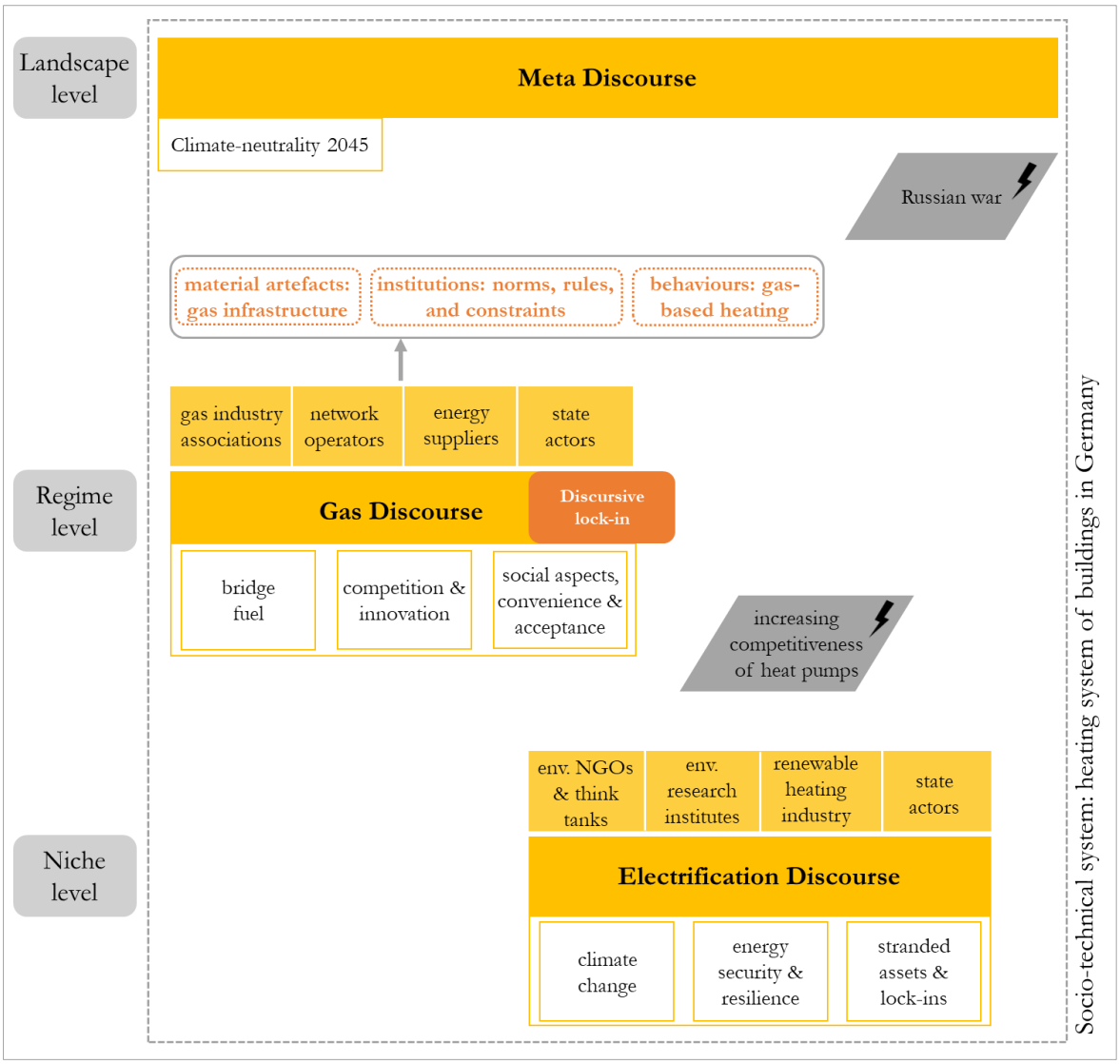

Figure 6-1. Visualisation of results – discourses, narratives, and implications for the heat transition in the German building sector
Source: Own presentation

6.1 Discourses and Narratives

This section focuses on answering RQ1 by describing the main discourses and the identified respective narratives. First, the discourse coalitions are described, followed by the institutionalised gas discourse and the alternative electrification discourse. The implications of the discourses are described in section 6.2.

6.1.1 Discourse Coalitions

Based on the document review and interviews, the actors were grouped into discourse coalitions. This was possible as actors from the same actor group and coalition commonly used similar or the same narratives. It must be acknowledged that this division is only valid for the study at hand, as it is based on the interviews conducted and documents reviewed for this thesis and should not be understood as a generalisable categorisation.

In general, it was possible to group the identified actor groups into two coalitions: one coalition made of strong regime actors, most prominently a strong gas industry and gas lobby (GDC),

and the other coalition mostly represented by environmental organisations (EDC). While, in general, the gas coalition is a strong advocate for keeping gas in the heating system of buildings, the electrification coalition promotes a fast exit from gas for the heating of buildings and pushes for alternative heating solutions, especially heat pumps. Table 6-1 gives an overview of the two coalitions:

Table 6-1. Discourse coalitions

Electrification discourse coalition: niche actors	**Gas discourse coalition: regime actors**
environmental NGOs	gas industry associations
environmental research institutes and think tanks	network operators
renewable heating technologies industry	energy suppliers
national and regional state actors	national and regional state actors

Source: Own presentation

State actors were difficult to place in the two categories, as the three interviews conducted with state actors led to very diverging views. Therefore, it is assumed that state actors, also majorly depending on the political party or institution they are part of, can belong to either one of the two coalitions.

6.1.2 Meta Discourse

The meta discourse can be understood as the general construct of meaning in society, embedded in the general values, assumptions, and practices at the landscape level. Thus, the meta discourse is multifaceted, consists of various narratives, and is not specific to one actor or actor coalition, but rather more abstract and general. A detailed analysis of the meta discourse within the German heat transition would be out of the scope of this study, as the collected data was focused on more specific narratives around the role of natural gas. However, some common assumptions that are important to sustain the meta discourse could be identified based on the collected data. In general, the meta discourse contains the consensus on the need for a heat transition in the German building sector because of the climate crisis. This has become obvious as all interviewees mentioned the topic and based their argumentation on general awareness of the climate crisis. Furthermore, it became evident that there is the general assumption that in theory, there are different options on how to design the heat transition. Focusing on natural gas, this means, e.g., that even though not all actor groups see natural gas to play a role in the future heating of buildings in Germany, there was still the assumption that natural gas would in theory be available as an option.

One shared narrative in the meta discourse is the need to fulfil international climate agreements, meet climate targets, and reach climate neutrality by 2045. This has, without exception, been stated across all interviews and documents, thus including both coalitions. The actors have also highlighted that for them, the awareness and relevance of climate change have strongly increased in the last years, and most likely, they would have framed their answers differently if the interviews would have been conducted some years ago. Thus, the topic of the climate crisis has gained attention across industries in the last few years. Furthermore, as the respondents commonly referred to national and international climate targets and agreements, one finding is that those targets have a strong influence on actors from all sectors and can thus be seen as a crucial part of the fight against the climate crisis. The actors mentioned Germany's nationally announced climate targets, especially concerning the newly announced goal of reaching climate neutrality by 2045 in response to a decision of the German Federal Constitutional Court in April 2021 (Respondent 5, gas industry association; Respondent 16, renewable heating industry

association; Respondent 9, energy supplier, FNB Gas, 2021). For instance, an interviewee from a gas industry association stated: *"The gas industry is also committed to the 2045 targets"* (Respondent 4, gas industry association). Second, staying in line with the Paris Agreement has been mentioned in several documents and interviews (respondent 4, gas industry association; BVEG, 2022; FOES, 2021; Greenpeace, 2021).

Thus, the urgent need to act is recognised by both coalitions. However, the question of how to act and what strategies to pursue to reach the climate goals has been answered differently by the actors. The GDC argues that natural gas cannot play any role in a climate neutral scenario. For example, it has been stated: *"It is the declared goal of the German government to be carbon-neutral by 2045, and that can only be achieved with the use of renewables, which excludes gas"* (Respondent 16, renewable heating industry association). On the other hand, also the GDC states to want to reach climate neutrality; however, they see gas to play an important role in that transition (FNB Gas, 2021; Respondent 8, gas network operator; Respondent 6, gas industry association).

Nevertheless, it seems like a general awareness of the risks of climate change and the need to act have been recognised by both the actors of the GDC as well as the EDC. The meta discourse has been adapted to the climate change debate and the topic seems omnipresent, independent of the actor and coalition. This can be seen as a positive indicator of the potential to accelerate the heat transition, as general awareness and willingness to act seem to be given. As it has been emphasised by the actors, this awareness has substantially increased in the last years, also backed up by international climate agreements and national climate targets. However, the question remains whether this is just a framing strategy employed by the actors, or if the commitment is truthful. Thus, looking deeper into the two discourses on how to achieve the common goal is important to reveal the strategies and agendas of the two coalitions.

6.1.3 Institutionalised Discourse: 'Gas Discourse'

At the regime level, the institutionalised discourse is the 'gas discourse'. The general aim of the GDC is to keep gas in the heating system of buildings. The gas discourse can be seen as the institutionalised discourse at the regime level due to mainly two reasons. First, the large share of natural gas that is being used for the heating of buildings, especially when compared to the alternative, renewable solutions, shows the prominent status of gas. Second, the actors that follow the gas discourse have strong agency: This became obvious during the interviews, as the actors were often referred to as having a lot of power when it comes to decision-making processes about energy policies. The lobbying power of the gas industry was also mentioned in several interviews.

Figure 6-2 visualises the discourse along with the discourse coalition and the narratives. Especially gas industry associations loudly raise their voices in the debate around natural gas, and, e.g., publish a large number of papers and statements. Besides that, network operators, energy suppliers, and certain state actors follow the gas discourse. Three prominent narratives support the gas discourse: The bridge fuel narrative is strong, also majorly backed up by the narrative that renewables are not 'ready' yet, or not suitable, to take the heat transition to the next step. In the same regard, it is often mentioned that natural gas is the fastest, cheapest, and easiest way to accelerate the heat transition. Second, competition and innovation are often mentioned to defend the position of natural gas in the heating of buildings and prevent strict regulative measures that could ban fossil-based heating options. Furthermore, natural gas is portrayed as the most social, as well as the most convenient and highly accepted heating solution in society. Increasingly, the GDC also includes other gases besides natural gas in their discourse, especially hydrogen.

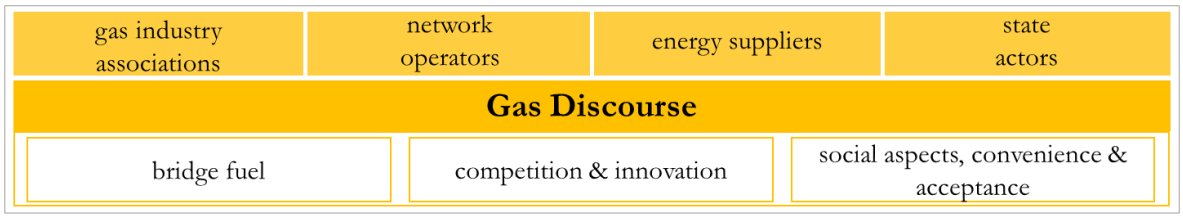

Figure 6-2. Gas discourse: narratives and discourse coalition
Source: Own presentation

Generally, the GDC sees natural gas to play an important role in the heating of buildings for a much longer period than the EDC. While the EDC states that natural gas should be phased out as quickly as possible (often mentioned is the phase-out from 2025 on), the GDC argues that such a fast phase-out is simply unrealistic. The actors claim that it will be impossible to replace the vast amount of gas-based heating systems due to practical reasons like the lack of skilled labour, but also due to a lack of acceptance from the building managers (Respondent 2, national state actor; Respondent 5, gas industry association; Respondent 10, energy supplier). Furthermore, they state that it will not be possible to upscale alternative, renewable energy sources fast enough to replace the natural gas-based heating (Respondent 1, national state actor; Respondent 6, gas industry association), or that the renewable heating solutions like heat pumps are not suitable for all types of buildings (Respondent 4, gas industry association; Respondent 5, gas industry association). The following statement of a representative of an energy supplier demonstrates this position well:

"The task of substituting 50% natural gas in less than 10 years is not really realistic. If we look at the facts: More than 20 million homes are heated with natural gas, so it will not be possible to phase out this infrastructure completely within 10 or 15 years, and honestly, probably we won't even be able to phase out natural gas as an energy source completely" (Respondent 9, energy supplier).

As highlighted in the statement above, some actors of the GDC think that natural gas will continue to play a role in the heating of buildings also in the middle and long run. While it is acknowledged that the need for natural gas will decrease, a complete phase-out is portrayed as unrealistic. Furthermore, solutions like using natural gas in combined heat and power plants are mentioned by some actors as a building block for the heat transition that includes natural gas in the long term (BDEW, n.d.-b).

However, most of the actors of the GDC acknowledge that natural gas should be fully phased out at some point (most refer to the year 2045 or 2050), however, it should be replaced with low-carbon gases like (green) hydrogen. In a paper by the association of supra-regional gas transmission operators, e.g., it is stated: *"Hydrogen and other climate neutral gases are essential for achieving overall climate targets and can specifically contribute to climate neutrality in the heating market."* (FNB Gas, 2021). In most of the interviews and documents within the GDC, the actors have mentioned hydrogen as the preferred replacement option for natural gas in the heating of buildings. The GDC generally portrays the future of hydrogen in a positive manner; seemingly optimistic that hydrogen will be largely available.

This is important, as it can be said that portraying hydrogen as the desired future heating solution strengthens the discourse of keeping natural gas as a bridge fuel. This is because the actors argue that natural gas infrastructure could be readjusted to be suitable for hydrogen in the future, and thus, a transition from natural gas to hydrogen is portrayed as the least disruptive option. Thus, the arguments the actors of the GDC made about the use of hydrogen are, for the purpose of

the study, being included in the gas discourse as a way of how the actors defend the role of natural gas as a valid bridge solution for the heat transition.

As also emphasised during the interviews, the actors of the gas industry see a chance for their business models to continue to play a role in the heat transition, as they expect to be able to simply switch their operations to hydrogen or other low-carbon gases. For example, a respondent from an association of energy suppliers confirmed that switching the business model from natural gas to hydrogen is considered a plausible scenario for a lot of energy suppliers (Respondent 10, energy supplier). As natural gas is a core business field for a lot of companies, including energy suppliers and network operators, a phase-out of natural gas could mean the end of their business as usual. Thus, the thought of being able to keep their business models and simply switch the type of gas is seemingly appealing to the GDC. Furthermore, a common argument has been that the gas infrastructure, which is currently used to transport natural gas, could be converted to transport hydrogen. This argument was also used to justify ongoing investments into gas infrastructure – while the fact that the infrastructure would need to be adjusted to hydrogen, at costs which are yet unknown, has not been mentioned by the GDC.

With regards to policy instruments, the GDC is generally opposed to introducing strict regulative measures like a ban on natural gas-based boilers. They argue that letting the market regulate itself is the most efficient and economical way, as excluding specific technologies would simply falsify the economic competition and thus lead to unnecessarily high costs. Furthermore, they argue that strict regulations often lead to reluctance to act at all – for example, a ban on natural gas-based boilers could lead to the fact that people would not change their boilers, but rather keep repairing and maintaining their old ones. For the GDC, clear financial and communicative support for hydrogen and a hydrogen strategy also for the building sector should be prioritised to accelerate the heat transition. They also state that subsidising boilers that are 'H_2-ready' would be a good bridge solution for gas boilers that need to be replaced in the short term.

In the following, the narratives that support the gas discourse are explained in detail. The actors have made use of those narratives mostly to defend the position of natural gas in the heating system of buildings, but also to justify the introduction of hydrogen to the heating system.

Bridge Fuel

The narrative that has been mentioned the most within the GDC is the bridge fuel narrative: The actors of the GDC commonly portrayed gas as the best way to accelerate the heat transition while the potential of renewable energy is still limited. For example, the federal association of natural gas, oil, and geo-energy Germany stated: *"Natural gas serves as a valuable bridge fuel here because it offers a constant supply and can compensate for the fluctuations of renewable energies in a timely manner"* (BVEG, 2022). Like in this statement, the actors commonly use the bridge fuel narrative when talking about natural gas. However, increasingly also hydrogen is mentioned. One respondent, for instance, mentioned that blue hydrogen, i.e., hydrogen that is decarbonised from natural gas, would be a suitable transition fuel from their point of view until green hydrogen would be available at a large scale (Respondent 5, gas industry association). In most cases, the respondents of the GDC see hydrogen as the 'end of the bridge', i.e., they think that the pathway should be from natural gas, and increasingly other forms of hydrogen and low-carbon gases, to green hydrogen ultimately (Respondent 1, national state actor; Respondent 6, gas industry association; Respondent 8, gas network operator; Respondent 10, energy supplier). This is important as the bridge fuel narrative gets strengthened by this vision of hydrogen being the best solution for the heat transition: According to the GDC, a smoother and less effortful transition from natural gas to hydrogen is possible than a transition based on electrification. Thus, already having a system that is based on (natural) gas will facilitate a transition to

hydrogen, as the infrastructure is already in place and only needs to be readjusted. In that sense, investments into the bridge fuel natural gas and the respective infrastructure are beneficial, as they will be used for hydrogen in the future.

The actors expect hydrogen to be increasingly available worldwide within the next decade, providing plenty of import opportunities for Germany. Furthermore, countering the argument of the high costs of hydrogen, they claim that with increasing demand and supply, prices would fall, making hydrogen competitive to the alternative options (FNB Gas, 2021). The GDC names various reasons why they see the switch to hydrogen as the preferred option. First, in line with the goal to reach the climate targets, they emphasise the positive characteristics and low climate impacts of green hydrogen. Second, it is stated that due to the limited potential of renewable energy production within Germany, the country will be dependent on energy imports also in the future – and transporting gas over long distances is more efficient than electricity (E.ON, 2020; FNB Gas, 2021). Furthermore, the GDC emphasises the characteristics of the German building stock, with most buildings built before the first German thermal insulation ordinance, and low refurbishment rates: These preconditions, according to the GDC, make it difficult to build the heat transition on heat pumps which operate more efficiently in well-insulated buildings. Thus, hydrogen could be the solution for those buildings (Respondent 8, gas network operator). Lastly, the GDC argues that the gas grid in Germany can be seen as a major asset that entails a lot of value. When switching to hydrogen, this asset could be utilised, as the infrastructure could be readjusted to store and transport hydrogen (Respondent 4, gas industry association). Furthermore, the GDC states that due to the infrastructure within the buildings, which is in most cases adjusted to an individual gas boiler, would need to be changed the least when switching from natural gas to low-carbon gases, whereas the switch to a heat pump often means bigger readjustments. Thus, switching to hydrogen could be the better accepted, but also the faster solution (Respondent 5, gas industry association; Respondent 7, gas network operator).

The bridge fuel narrative is strongly based on the GDC's premise that on the one side, the potential of renewable energy is limited, and a fast expansion of renewable energy production is not realistic, and on the other hand, solutions based on renewable energy are not suitable to advance the heat transition on their own. With regards to the first point, it has, for instance, been stated: *"If you look at the heat market …, we haven't managed to increase [the share of renewable energy] significantly in 20 years. That's why it's difficult to suddenly switch and say I have to electrify everything, which means I would need to have a gigantic expansion of renewable energies. To provide electricity from renewable energies in Germany is just as much a bet on the future as betting on renewable gases*" (Respondent 5, gas industry association). Thus, the respondent expressed uncertainty about the capacities of renewable energy production within Germany. This view has been shared by several interviewees and in several documents. The association of supra-regional gas transmission operators also highlighted that the electricity system was currently not designed for a widespread electrification of heat demand and that a quick increase of capacities would be challenging, or even impossible in the near future (FNB Gas, 2021). Furthermore, the association mentioned that due to limited space available, the potential for the expansion of renewable energy production would be limited, and, e.g., the expansion targets for onshore wind power capacity are already lagging behind the German expansion targets.
Regarding the second point, the GDC listed several aspects as to why they do not think that renewable energy is suitable to advance the heat transition in the near future. One argument that has been made in several interviews is seasonal fluctuations in renewable energy production. While during the winter months the heat demand is the highest, production capacities of renewable energies usually decrease. Thus, to meet those peak demands, the GDC sees gas to play a crucial role (Respondent 1, national state actor; Respondent 8, gas network operator). In that regard, also the better storage capabilities of gas compared to electricity have been

mentioned, for instance in the following statement: *"Why the molecule [natural gas] is so important for the heat market is because it can be stored. And this is particularly relevant when you look at the peak load in winter, then we clearly see that these peaks cannot be met by renewable electricity and heat pumps"* (Respondent 8, gas network operator). Another argument that has been brought up to demonstrate the limited potential of renewable energy and the need to have natural gas as a bridge fuel is the characteristics of the German housing stock. Due to the low refurbishment rates and the heterogeneous building stock, the GDC argues, the building sector would not be ready for a switch to renewables. A widespread refurbishment of the buildings, which would be needed to make the buildings suitable for heat pumps, would take a long time, and until then, gas should be used in that transition phase.
Thus, by highlighting the limited potential of an increase in renewable energy production, and by the limitations of renewable energy to meet the heat demands of the German building stock, the GDC argues that natural gas, as well as, e.g., blue hydrogen, are relevant bridge fuels. Furthermore, as the potential of renewables is also not expected to increase to the needed extent, according to the GDC, hydrogen will be needed at the end of the transition phase.

Furthermore, to emphasise the potential of natural gas as a bridge fuel, the actors of the GDC commonly mentioned its positive climate impacts, as well as the potential to quickly reduce CO_2 emissions. In several of the interviews and documents, it has been stated that natural gas is the 'cleanest of all fossil fuels' (Respondent 2, national state actor; Respondent 5, gas industry association). Especially due to the still high percentage of oil-based heating, a switch to natural gas is seen as favourable. For instance, in a document of the federal association of the energy and water industries, it is described: *"A calculation shows: If all households that currently heat with oil were to switch to a gas condensing boiler at places where gas networks are already in place, 18 million tonnes of CO_2 could be avoided"* (BDEW, n.d.-b). According to the federal association of natural gas, oil, and geo-energy Germany, this switch from oil to natural gas would lead to CO_2 emissions reductions of up to 50%. (BVEG, 2022). However, also if the heating was already based on natural gas, a switch to more efficient gas condensing boilers can bring considerable amounts of emission reductions. This switch from oil or gas to (more efficient) natural gas-based heating would, according to the GDC, be a lot easier and faster than switching to renewable energy solutions. In that respect, the actors often mentioned the urgency to act if climate targets shall be met – thus, the fastest possible solutions for emission savings should be chosen. One respondent stated, that "*climate protection is when I save CO_2, and not necessarily when I use renewable energy"* (Respondent 5, gas industry association). Thus, they also argue for a fast switch to natural gas to realise emission savings in the short term.

In general, the GDC is portraying gas as the fastest, cheapest, and easiest solution for the heat transition, and therefore central as a bridge solution. As the potential of renewable energy is limited, and natural gas can lead to fast emission reductions, the heat transition would profit from using gas as a bridge fuel. Besides the fast emission savings that can be achieved by switching to efficient natural gas-based heating systems, the costs would also be lower than building the heat transition on electrification. The interviewees commonly highlighted the high costs of heat pumps and extensive refurbishments, whereas the exchange of a gas boiler, if the rest of the infrastructure does not need to be changed, is much cheaper (Respondent 4, gas industry association; Respondent 7, gas network operator). Furthermore, ultimately the switch to hydrogen, which is seen as the end goal, would be easier if a gas infrastructure already exists, which is another argument for using natural gas as a bridge fuel. In general, the respondents also highlight that the easiest and least disruptive way for the heat transition is the preferable way, in order not to place an unnecessarily high burden on the society and increase acceptance (Respondent 5, gas industry association).

Free Competition and Innovation

'Technologieoffenheit' [literal translation: technology openness/ technology neutrality] has been a keyword that has been used repetitively by the actors of the GDC, which means as much as an approach that does not give preference to certain technologies. The actors of the GDC argue that giving a strong preference to, e.g., heat pumps, and proactively deciding on a phase-out of natural gas or a ban of hydrogen in the heating market, should be avoided (Respondent 5, gas industry association; Respondent 7, gas network operator). Furthermore, the terms 'competition' and 'innovation' have been mentioned in various interviews and documents by the GDC, with the same goal of not giving preference to certain technologies over others. For example, it has been stated: *"Germany has always done best when there is free competition and "Technologieoffenheit" [technology neutrality]. Then there will be innovation and inventiveness"* (Respondent 4, gas industry association). It has been highlighted that Germany is the 'country of engineering' and a highly innovative and competitive economy, and thus, any restrictions that could diminish this competition should be avoided.

The GDC is opposed to introducing strict regulative measures as they are supported by the EDC. In contrast, the GDC states that the market should regulate which technologies are being used. For instance, it has been argued that *"a premature and one-sided commitment to specific technologies … carries the risk that climate neutrality in the heating market will not be achieved or will only be achieved at unnecessarily high economic costs"* (FNB Gas, 2021).

As emphasised in the statement above, the GDC bases their argument for a technology-neutral approach on several aspects. First, they state, that costs would be unnecessary high if certain technologies are given preference, as free economic competition is hindered. They refer, e.g., to the high costs that would be needed to subsidise heat pumps to make them competitive, or the high costs that would be needed for building refurbishment. Furthermore, according to the GDC, meeting the climate targets would be in danger of not being met if certain technologies, like hydrogen, would be banned for the heating of buildings. They argue that focusing on one specific technology, like heat pumps, could slow down the heat transition, due to "*a combination of the heterogeneity of the building stock, the high market penetration of gas- and oil-based heating systems, the challenges of refurbishments and the remaining time to achieve climate neutrality*" (E.ON, 2020). Thus, it is argued that a wide range of technologies (including natural gas and hydrogen) are needed to meet the challenges of the heat transition.

Social Aspects, Convenience, and High Acceptance

The last narrative feeding into the gas discourse is portraying a heat transition based on gas as the most social, convenient, and thus also most accepted solution. This is also connected to the narrative of natural gas being the cheapest and easiest way to reduce carbon emissions (e.g., when switching from oil to gas or switching to a more efficient gas boiler).

It was commonly mentioned in the interviews with representatives of the GDC that social implications of the heat transition need to be considered (Respondent 7, gas network operator; Respondent 6, gas industry association; Zukunft Gas, 2021). In that sense, the respondents commonly referred to the high initial investment costs of heat pumps, in comparison to the lower costs of switching from oil to gas or from gas to a more efficient gas boiler. Therefore, according to the GDC, switching to efficient natural gas-based heating technologies or low-carbon gases would be the cheapest and easiest way for low-income households to reduce the carbon emissions of their heating. For instance, the argument of social implications has been mentioned in a study of the energy supplier E.ON on decarbonisation pathways for the German city of Essen. They found that a transition based on heat pumps and building refurbishment would lead to a steep increase in costs, especially for low-income neighbourhoods. This is especially because the high refurbishment rates would lead to a disproportionate increase in the

share of income lower-income households would need to spend on heating. Instead, a heat transition that includes 'green gases' would be more socially acceptable, as costs would be distributed more evenly across the income classes. This study has also been referred to in other documents, such as the publication "The value of hydrogen in the heating market" by the association of supra-regional gas transmission operators (FNB Gas, 2021), as well as in the interviews with the actors of the GDC.

Furthermore, the GDC highlighted, that "*the people who have the most money also live in the newest buildings and have the newest heating*" (Respondent 4, gas industry association). For those types of buildings, they acknowledge that heat pumps are a good solution. However, as it has been highlighted by the GDC, heat pumps are, due to their higher efficiency in buildings with better energy standards, a technology for people of higher income classes that can afford to live in those buildings. In contrast, people with lower incomes tend to live in less energy-efficient buildings and do neither have the liquidity to invest in building refurbishments nor to purchase a heat pump. According to the GDC, it cannot be expected that those people must spend large amounts of money to play their part in the heat transition. Instead, they should get the most economical solution – which could be natural gas, or hydrogen in the future. This would also increase the acceptance of the heat transition across society (Respondent 7, gas network operator). Thus, lower costs would be one reason why a heat transition based on gas would lead to a higher social acceptance.

The second reason why a gas-based heat transition would be better accepted in society, according to the GDC, is the higher convenience that gas offers. This refers both to the comfort and convenience of natural gas-based heating, as well as to the higher convenience – or lower inconvenience – of switching from natural gas to hydrogen instead of switching to a heat pump. Referring to the high comfort and convenience of natural gas, one respondent highlighted: *"Above all, it is a comfortable energy source. And that has led to people taking advantage of the offer and choosing it because it was cheap, clean, and extremely comfortable*" (Respondent 5, gas industry association). Another respondent explained that the high convenience also comes from the fact that a gas-based heating system can flexibly be turned on and off, and due to the high-temperature levels, rooms can be heated up quickly. In contrast, when using a lower temperature system, e.g., with heat pumps, the room temperature takes longer to adjust, and it is less flexible in its operation (Respondent 2, national state actor). Second, the GDC emphasises that switching from oil to gas, switching the gas boiler to a more efficient model, or in the future switching to hydrogen relates to less inconvenience for the building managers and inhabitants. For example, one respondent described: *"If we look at the figures, we see how many natural gas-based heating systems were installed last year. Why is that the case? These are all just people saying that this is an elegant way, I don't have to do anything to my house, I can get a new heating system and save 20, 30% from scratch … Especially if I had oil-based heating, that's the best way."* (Respondent 6, gas industry association. From this statement, again, the GDC highlights the fact that building refurbishments would be needed at a high level for a heat pump roll-out, which would lead to inconveniences and costs for the building managers and inhabitants. Furthermore, the old infrastructure within the buildings would need to be changed for heat pumps or the connection to a heat network, whereas the infrastructure could be kept when keeping gas as an energy source.

6.1.4 Alternative Discourse: 'Electrification Discourse'

At the niche level, the alternative discourse is the 'electrification discourse'. The general aim of the EDC is to achieve a complete phase-out of natural gas in the heating of buildings as soon as possible, and not to allow alternative gases like hydrogen as heating solutions. They see the electrification of the heating of buildings, i.e., mainly the use of heat pumps, but also an increasing share of buildings connected to decarbonised heat networks, as the most important solutions for the heat transition. The electrification discourse is located at the niche level, as of

now, the share of renewable energy-based heating systems in Germany is low, e.g., the share of electricity-based heating (including heat pumps) is only about 5% (AEE, 2021a). Furthermore, the discursive agency in the natural gas debate of the actors of the EDC is perceived to be lower than the one of the gas lobby, as it has been highlighted during the interviews. However, with sales figures growing strongly and steadily (BWP, 2022), and increasing support and acceptance, the electrification discourse is gaining ground.

Figure 6-3 visualises the discourse along with the discourse coalition and the narratives. Environmental NGOs, think tanks, and research institutes are strong proponents of the EDC, as well as the renewable heating industry and certain state actors. The most prominent narratives concerning natural gas in the heating of buildings are climate change and the negative climate impacts of natural gas. Furthermore, energy security and resilience are often mentioned, especially as a reaction to the Russian war and its implications on the natural gas supply. Lastly, stranded assets and lock-in effects are often referred to in connection to natural gas.

Figure 6-3. Electrification discourse: narratives and discourse coalition
Source: Own presentation

"*We are coming out of the fossil age and going into the electricity age*" (Respondent 2, national state actor). This statement of a national state actor demonstrates the general pathway the EDC proposes. They argue that any fossil fuel-based energy carrier, including natural gas, needs to be phased out as soon as possible. In a carbon-neutral world, they argue, fossil fuels cannot play any role. Thus, the actors of the EDC are in favour of strict regulative politics that would lead to a phase-out of natural gas in the heating of buildings. The interviewees were all supporting the proposed minimum standard of 65% renewable energies in every newly installed heating system from 2025 on that has been proposed by the new government. Furthermore, they highlight the urgent need to propose a natural gas exit strategy accompanied by communication and information campaigns to increase the awareness in society of the needed heat transition. The urgency to act and implement these measures as soon as possible has also been emphasised by the interviewees: *"From my point of view, all levers must be set in motion at the same time, i.e., price instruments, regulatory instruments as well as planning instruments … For example, the price instruments must lead to fossil fuels, i.e., natural gas, becoming more expensive to make investments in renewable heating technologies financially more attractive for the building sector"* (Respondent 11, environmental NGO).

The EDC states that the most important solutions for the heat transition are heat pumps operating with renewable electricity and decarbonised heat networks (BEE, 2021; Respondent 13, environmental research institute). With heat pumps, the EDC argues, *"… the building sector has a decisive advantage over other sectors with similar ambitious climate targets, such as industry and heavy goods transport: decarbonisation technologies are already available and established"* (BWP, 2021). While these other sectors are dependent on high-temperature systems and thus will need green hydrogen in the future for their decarbonisation, the heating of buildings, according to the EDC, works well with lower temperature systems. Thus, heat pumps should be the preferred option, especially for detached and semi-detached buildings, but they are also suitable for most other building types. As opposed to the statements of the GDC, the EDC argues that heat pumps can also be used in unrenovated buildings – less efficient than in fully insulated buildings, but still

in most cases more efficient than, e.g., hydrogen (BWP, 2021; Respondent 15, renewable heating industry association; Respondent 14, environmental think tank). Furthermore, the EDC highlights that for a successful heat transition, as it has also been shown in all modelled scenarios, high renovation rates will be needed in any case to reduce the energy demands of buildings, which is also favourable for a roll-out of heat pumps. Countering the arguments of the GDC, the EDC also considers the possibility of quickly rolling out heat pumps to be larger if political measures adjust quickly. Furthermore, they also acknowledge the challenges of a shortage of skilled labour. However, the EDC states that the capacities will increasingly be available if there is political support. Additionally, by improving heat planning and spreading out labour capacities over the entire year instead of having a peak demand for heat technology exchange and repair during the winter months, the situation could be eased (BEE, 2021).

In addition, the EDC states that heat networks will play a crucial role in the heat transition. Existing heat networks need to be decarbonised, for example by using large heat pumps, geothermal energy, or waste heat, and new heat networks need to be designed (Respondent 1, national state actor; Respondent 13, environmental research institute). This is especially important for cities and densely built areas. In that sense, municipal heat planning has also been mentioned as an important instrument to facilitate the realisation of heat networks. There are, according to the EDC, large unused potentials for renewably generated heat, from waste heat from industry, geothermal energy, solar thermal energy, and ambient heat. The FOES, a think tank and NGO, estimates that by the end of this decade, sufficient renewable heat for the building sector can be generated in Germany, so that a phase-out of the use of all fossil fuels, including natural gas, is feasible (FOES, 2021). Other actors from the EDC generally agree with the large potential of renewable energy, however, also highlight the need for political action to accelerate the potential of renewables (BEE, 2021; Respondent 15, renewable heating industry association). Especially price signals are crucial according to the EDC: The price of fossil fuels needs to increase drastically through the inclusion of external costs in their price and the removal of state support, and subsidies for renewable energy need to increase. These price signals need to be communicated clearly to consumers, for them to plan their expenses for energy in the long term and have the necessary security to invest in renewable heating technologies.

With regards to low-carbon gases, the EDC argues that relying on a still scarce and expensive energy carrier like hydrogen is not a resilient path. The potentials, costs, environmental benefits, and technical feasibility of hydrogen are too uncertain to build the heat transition on hydrogen. Furthermore, as it has been emphasised during various interviews, if hydrogen would be available in larger amounts in the future, it would be needed for industries that rely on high-temperature levels (e.g., the steel and metal industry), and that thus would also be willing to pay the higher prices. In contrast, for the heating of buildings, lower temperature systems, such as heat pumps, are sufficient. Furthermore, the EDC often highlights that the efficiency of heat pumps is far higher than the efficiency of using hydrogen for heating (Greenpeace, 2021). This statement by a representative of a renewable energy association summarises the general position of the EDC towards hydrogen well: *"We don't see hydrogen in the building sector and in heat networks at all. Because it is not necessary; the technologies to supply the building sector with renewable energy are there. And no one knows when hydrogen will be available, to what extent, and at what cost. That's why we shouldn't wait for a possibility to arise at some point, especially because the market is so rigid. We really can't afford to wait any longer, we must act now"* (Respondent 16, renewable heating industry association). The statement also highlights the urgent need to act immediately and the importance of choosing a resilient pathway for the heat transition and focusing on such-called 'no-regret-measures'. As the heating structure changes so slowly over time, it is crucial to implement measures now that will bring positive climate impacts without a doubt. For example, it usually takes more than 20 years until a heating system gets exchanged – thus if an 'H_2-ready' gas boiler gets installed now in the hope that hydrogen will be available in the future, the likelihood of the building manager

being willing to switch again after a few years if it is realised that hydrogen is not available, is low.
In general, the EDC sees the calls to include hydrogen in the heating of buildings to be a "*vehicle for giving the gas industry a perspective for the future*" (Respondent 3, national state actor). In several interviews, it has been mentioned that the attention that has been given to hydrogen in the heating sector has been a result of actors from the gas industry loudly advocating for that (Respondent 13, environmental research institute; Respondent 16, renewable heating industry association). Nevertheless, the EDC emphasises, when looking at scientific studies both about the characteristics of hydrogen as well as about the potentials of heat pumps and heat networks, the case in favour of the latter is clear.

In the following, the narratives that support the electrification discourse are described.

Climate Change

The climate crisis as well as the negative climate impacts of natural gas can be seen as the basis of the argumentation of the EDC. While both coalitions share the narrative of the need to fulfil climate targets, the EDC has a much stronger focus on why that need exists and why natural gas cannot be a part of a decarbonised future. Thus, most interviewees of the EDC mentioned the urgent need for decarbonisation of the heating of buildings because of the mounting climate crisis (Respondent 11, environmental NGO; Respondent 13, environmental research institute). Furthermore, that has been the focus of several documents belonging to the EDC (FOES, 2021; Greenpeace, 2021). The actors emphasise that fossil fuels cannot play a role in a decarbonised future, and thus, natural gas needs to be phased out as fast as possible. Furthermore, compared to the GDC, the EDC has a much stronger focus on the consequences of fossil fuels like natural gas on the climate crisis, e.g., reaching tipping points of the climate system like the thawing of permafrost (Greenpeace, 2021).

The EDC especially highlighted that there has long been a misconception about the characteristics and climate impacts of natural gas, which was one reason why the 'bridge fuel narrative' has been successful. As described in the following statement, the problem of methane leakages has, according to the EDC, long been unknown: *"If you only look at the CO_2 emissions of natural gas, you can see that less CO_2 is released while burning natural gas than when burning coal. And if you only take that into account, then that is a valid argument for deciding to use gas instead of coal. However, methane emissions, which are even more harmful to the climate than CO_2, and which are released at various points in the supply chain of natural gas imports, through so-called methane leakages, are not considered. And it was simply not clear, for a long time, that we have those methane leakages and that they are a problem"* (Respondent 11, environmental NGO). Several interviewees mentioned this fact, and that only in recent years, attention has been given to the problem and an increasing number of studies have been conducted to measure the methane leakages. This has also raised the awareness among the environmental actors of the negative climate impacts of natural gas. In that regard, the reason why methane emissions are so problematic has been highlighted in several documents: They state that methane is a much more potent GHG than carbon dioxide and can heat the atmosphere 84 times as much as CO_2 within twenty years (FOES, 2021). Thus, it has been concluded that "*if the total life cycle emissions [of natural gas] are taken into account, the climate impact can possibly be as negative as for coal*" (DUH & DIW, 2021).

In that sense, the actors also highlighted the high external costs of natural gas, i.e., costs that are not borne by the polluters themselves but are passed on to society or third parties. The external costs of natural gas are on the one hand the consequential costs of climate change, which are intensified by using fossil fuels such as natural gas that lead to emissions that are harmful to the climate. On the other hand, the combustion of fossil fuels also releases other air pollutants that can cause health problems, which leads to costs for the health care system. The document review

included a study which found that around 75% of the climate change costs of natural gas are currently not yet internalised in the price (FOES, 2021). This, according to the EDC, leads to false incentives for end customers and has been one reason why natural gas has been used so widely in the heating of buildings (Respondent 11, environmental NGO).

The EDC highlighted that those two aspects, the long unknown climate impacts of natural gas and its low costs, were two reasons why the 'bridge fuel narrative' has been successful. As it was thought that natural gas would lead to improved climate impacts compared to coal and oil, this also allowed the gas industry to portray natural gas as a 'clean and climate-friendly' energy source (DUH & DIW, 2021; Respondent 13, environmental research institute). Thus, an easy and fast opportunity for emission savings was seen in the switch to natural gas. Furthermore, natural gas was so popular as a bridge fuel because of its low costs. However, as pointed out by the EDC, these low prices did not take the climate costs of natural gas into account. If the external costs of natural gas would be internalised, its competitiveness in the heating market and its popularity would decrease. Thus, the EDC concludes that if the negative climate impacts and the high external costs would be taken into account, this shows that natural gas is not a suitable bridge fuel and should be phased out as fast as possible.

Energy Security and Resilience

The narrative of energy security and resilience emerged as a reaction to the Russian war, which shed light on the dangers of the high dependency on energy imports. The EDC highlighted that there has been far more attention to the negative consequences of fossil fuel dependencies and the need for an energy transition. Several interviewees mentioned that before the war, the topic of energy security would have played a far less important role. For instance, the interviewees reported that more enquiries about the potential of renewable heating technologies had reached them, and that in general there was increased attention from politics and society on the topics of heating and natural gas (Respondent 3, national state actor; Respondent 14, environmental think tank). This also becomes obvious when comparing the reviewed documents with the interview results: While the topic of the Russian war and energy security has been mentioned in most interviews with actors of the EDC, the argument has not been included in the documents which have been published before the outbreak of the war.

The exploding gas prices, the increasingly empty gas storages, and the fear of Russia completely shutting down their gas supply are risks that have been mentioned by several actors of the EDC. This showed, as pointed out by a respondent of an environmental NGO, how dependent Germany had become on energy imports from Russia. While acknowledging that a fast reduction of gas imports would be challenging, the actor sharply criticised the ongoing payments for energy imports from Russia: *"There should be a big discussion about the fact that we are currently financing a war through the use of natural gas"* (Respondent 11, environmental NGO). Thus, decreasing this dependency should be prioritised according to the actors of the EDC, and the actors see *"momentum for a natural gas phase-out"* (Respondent 11, environmental NGO).

To increase energy security and resilience, the actors of the EDC consider the fast expansion of renewable energy to be crucial. For instance, it has been highlighted that *"… the pressure has increased to switch to renewable energies because this also makes us more self-sufficient and not dependent on imports"* (Respondent 16, renewable heating industry association). In that respect, it has also been emphasised that the focus should be on so-called 'no-regret measures': As it is shown that heat pumps work efficiently for most buildings, building the heat transition on electrification is seen as a resilient path that will increase energy security and lead to positive climate impacts at the same time (Respondent 13, environmental research institute). Thus, the focus should be on expanding renewable energy production and phasing out gas-based heating to decrease the need for gas imports. Importantly, the actors emphasised that the threat of an energy should in no

case lead to a prolongation of the allowance to produce nuclear and coal energy. A resilient way must, according to the EDC, be compliant with a pathway fighting the climate crisis.

Furthermore, the actors of the EDC highlighted that the awareness in society of the topic of energy security has increased. For instance, one representative of a renewable heating industry association stated: *"Among other things, this has led to the question: If I have gas-based heating now, will I also have gas next year? Not to mention the question of what it will cost. In this respect, I think a lot of people are concerned right now about whether they have an alternative"* (Respondent 15, renewable heating industry association). The EDC described that before the war there was a general feeling of security in society that gas was a stable, cheap, and secure source of energy, so no need to change was seen. However, that changed now, and people began to think more about their energy needs, and how they could secure a stable energy supply for their buildings. This could, according to the EDC, be seen as a chance to act and accelerate the heat transition (Respondent 11, environmental NGO; Respondent 13, environmental research institute). While before the war there has been a lack of awareness that hindered the heat transition, this has changed now, and the willingness amongst society to exchange their gas-based heating system could be higher.

Stranded Assets and Lock-Ins

The last narrative that has commonly been mentioned by actors of the EDC is the risk of stranded assets and lock-ins. The narrative has been used by most of the interviewees and in most of the documents of the EDC when talking about the role of natural gas in Germany's heat transition.

Focusing on stranded assets or stranded investments, the actors highlighted that to stay in line with climate targets, natural gas will need to be phased out as soon as possible. Thus, gas infrastructure, including both the gas grid and the technology within the buildings, will not be needed to the same extent or not at all in the future. Accordingly, investments into gas infrastructure today will likely lead to stranded assets. This has, for example, been explained in a document by the German environmental think tank 'Agora Energiewende': Looking at the large investment sums that are considered to be necessary according to the gas network development plan or by gas network operators, *"… the figures give the impression that the gas grids will have the same importance in the future as they do today. Yet we know: This planning of the gas infrastructure is wrong. Significant cost traps are being set up here for heating customers and taxpayers"* (Agora Energiewende, 2021). Furthermore, the text outlines that when it comes to a phase-out of natural gas, high transition and compensation payments for the gas industry would accrue, as it had been the case with the coal exit, making the transition even more expensive.

A commonly brought up example regarding gas lock-ins are investments into the expansion of regional gas distribution grids. The costs of the gas grids are partly covered by 'grid fees' of the end customers. However, if an increasing number of households switch to alternative heating technologies, those fees are carried by fewer customers. This would mean that the maintenance of those distribution grids would be uneconomical, and increasingly, the grids would need to be decommissioned (Respondent 13, environmental research institute; Respondent 12, environmental NGO). The actors also highlighted that these investments are incentivised by 'attractive investment conditions' by the German network agency (Respondent 14, environmental think tank). Another example that has been brought up is the risk of lock-ins in connection with the construction of new gas power plants. According to the EDC, a key driver for the construction of gas-fired power plants was the federal government's subsidy regime, which clearly favoured combined heat and power plants and thus primarily fossil fuel plants compared to renewable heat (Respondent 12, environmental NGO). This led to "misguided climate policy incentives with the risk of a gas lock-in or stranded assets financed by tax payments" (DUH & DIW, 2021). As usually, a technical-economic lifetime of 45 years for

natural gas power plants is assumed, this would mean that power plants that are constructed today would be operating until 2065 or 2080, which is in massive contradiction to climate policy necessities.

The actors of the EDC criticise that even though the negative climate impacts of natural gas and the need for a heat transition are known, the German government continues the gas-friendly subsidies and keeps investing in gas infrastructure, including the expansion of the gas grid, or the construction of gas import pipes and LNG terminals (Respondent 12, environmental NGO; Respondent 14, environmental think tank). Instead, the EDC advocates for stopping any investments into natural gas infrastructure, except for necessary maintenance work, to avoid stranded assets.

Regarding lock-in effects, the actors mentioned especially the risk of creating infrastructural carbon lock-ins in connection with the gas grid, but also with the installed infrastructure in the buildings. For instance, it has been stated: *"Whenever investments are made in the expansion of gas grids, there is already a lock-in. In individual buildings: Every heating system installed is a lock-in because it can be assumed that it will run for the next 20 years"* (Respondent 12, environmental NGO). Due to the longevity of the building and heating technologies, as well as long investment cycles, the building sector is especially prone to lock-in effects. The actors highlighted that once a new heating system is installed, it usually stays in the building for more than 20 years. This would make a switch to renewable energy more difficult, as the acceptance of the households to switch again – before the end of the lifetime of their heating technologies – would be lower (Respondent 15, renewable heating industry association; Respondent 14, environmental think tank). In addition, the involvement of many individual decision-makers in the building sector makes the heat market especially rigid (Respondent 16, renewable heating industry association). Thus, to avoid lock-in effects, a ban on the instalment of new gas-based heating and a clear strategy for a phase-out of natural gas-based heating technologies would be crucial.

Furthermore, the EDC emphasised that investments into gas infrastructure would likely lead to lock-in effects. In that respect, the widely discussed Nord Stream 2 pipeline, as well as the construction of LNG import terminals, have often been referred to. For instance, it has been stated: "*Both the LNG terminals and Nord Stream 2 are at risk of a fossil lock-in: Because the fossil investments only pay off if they remain in operation for decades, they could lead to a severe delay in the energy system transformation"* (Greenpeace, 2021). The actors expressed concern that once the infrastructure is in place, the economic arguments for exploiting the entire life cycle would be stronger than the environmental arguments for the need for a fossil phase-out (Respondent 11, environmental NGO). Thus, those investments should be avoided to avoid fossil fuel path dependencies and a dangerous delay of the heat transition.

In addition, the actors of the EDC highlight that another mechanism that enforces gas lock-ins is the framing of the gas industry that the natural gas grid could be converted into a hydrogen grid in the future (Respondent 12, environmental NGO). This framing, according to the EDC, allows the gas industry to defend ongoing investments into natural gas infrastructure that will likely lead to lock-ins in the future. *"It is often the case that the gas lobby wants to keep expanding its gas networks and then says it can simply be converted to hydrogen later. However, it just doesn't work that way …, the conversion is not so easy and large retrofitting measures would be needed. But it is precisely this argumentation that can lead to lock-in effects"* (Respondent 16, renewable heating industry association). The same strategy, according to actors of the EDC, has been applied regarding the heating technologies within the buildings: *"It is a strategy of the gas heating manufacturers to continue selling gas heating as long as possible. And then, because of the many customers, to be able to force the federal government to adopt a renewable gas strategy, because then there are no other options. This creates deliberate path dependencies"*

(Respondent 12, environmental NGO). Thus, the actors of the EDC consider the gas lobby to play a large role in reinforcing the lock-in effects of natural gas.

Lastly, the EDC emphasised the risks of those lock-in effects: *"The resulting lock-in effects have tangible consequences for the transformation process: Currently, the expansion of renewable energies and measures for energy efficiency and sufficiency are being slowed down by the further expansion of natural gas infrastructure"* (DUH & DIW, 2021). As highlighted in this statement, carbon lock-ins into natural gas would dangerously slow down the heat transition. Thus, it is crucial to avoid lock-ins into natural gas, by preventing investments into non-necessary gas infrastructure and developing a clear phase-out strategy for natural gas in the heating of buildings.

6.2 Implications of Discourses: Lock-In Effects and Potential for Change

As discussed in the theoretical framework, it has been shown in the literature that discourses and narratives can play an important role in shaping policies and transition processes, as they entail particular framings and goals that suggest and justify certain actions and strategies. In doing so, discourses can lead to the creation of discursive lock-ins, and, building on the understanding that discourses are reproduced in social practices, behavioural, institutional, and infrastructural lock-ins. Furthermore, discourses can also help incumbent actors to defend their regime or align transitions to their interests. Yet, discourses can also play a role in accelerating change and undermining dominant socio-technical regimes. Thus, this section analyses the potential implications of the discourses about the role of natural gas in Germany's heat transition in the building sector that have been outlined in the previous sections, thereby answering RQ2. It is suggested that the dominant gas discourse has led to a discursive lock-in which can, to some extent, explain the ongoing support for natural gas and the deceleration of the heat transition.

6.2.1 Discursive Lock-Ins and Implications for Infrastructure, Behaviours, and Institutions

Three types of discursive lock-ins that can lead to the stabilisation of a socio-technical regime and potentially the creation of lock-ins have been considered within this study: At the meta level, unchallenged values and assumptions of the meta-discourses can lead to a discursive lock-in. Second, at the regime level, the incumbents' strong discursive agency can lead to a discursive lock-in of their institutionalised discourse. And third, at the niche level, there can be a risk to create a discursive lock-in either if the alternative discourse is too radical to be reproduced, or too close to the institutionalised discourse to have transformational power.

Neither a discursive lock-in at the meta level nor at the niche level have been identified. The meta discourse has been adapted to the climate crisis debate, and there is a general agreement on the need for transformation within Germany's energy and heat system. This is important because if the values, actions, and goals proposed by the meta discourse would be opposed to the general understanding of the need to fight the climate crisis, it would generally be more difficult to challenge the technologies, institutions, and behaviours of that status quo. However, the actors of both coalitions highlighted that for them, the awareness and relevance of climate change have strongly increased in the last years. Thus, the topic of the climate crisis and the need to fulfil climate targets have reached the meta level and are thus generally not questioned by the actors. Therefore, in the context of the heat transition in the building sector, there is no discursive lock-in at the meta level that would lead to fossil path dependencies. At the niche level, there can be a risk to create a discursive lock-in either if the alternative discourse is too radical to be reproduced, or too close to the institutionalised discourse to have transformational power. However, in the case of this study, the alternative discourse is neither too radical nor too

marginal. The alternative discourse differs from the regime discourse quite substantially in advocating for a phase-out of natural gas in the building sector and the prioritisation of electrification. Furthermore, the discourse can be considered as not too radical as the suggested pathways are already being implemented and are gaining support. Thus, there is no discursive lock-in at the niche level that would hinder the dismantling of fossil-free heating technologies.

However, at the regime level, a discursive lock-in has been identified. For this study, it is understood that a discursive carbon lock-in is reached if institutionalised mechanisms of discursive reproduction "include mechanisms of reproduction related to a mental map (or discourse) based on increasing returns" (Buschmann & Oels, 2019, p. 4). This is because developing a basic understanding of a certain socio-technical matter requires high initial costs and learning efforts, and thus, employing a mental map, i.e., following a certain discourse, is easier. In other words, as following a given discourse on a topic requires less effort than forming an understanding oneself, societal and political actors tend to follow such discourses provided by dominant actors. This leads to discourses of dominant actors being reproduced more, as they have the means and credibility to reach and influence people's opinions and actions. In this context, this means that since forming an understanding of the complex interplay between environmental, social, technical, economic, and political factors around natural gas is very complicated, people prefer to follow the discourse provided by the credible regime actors. Thus, in the context of this study, a discursive lock-in would be reached if the institutionalised discourse is increasingly reproduced and thereby justifies and constitutes the institutions, behaviours, and infrastructure of the natural gas-based heating system.

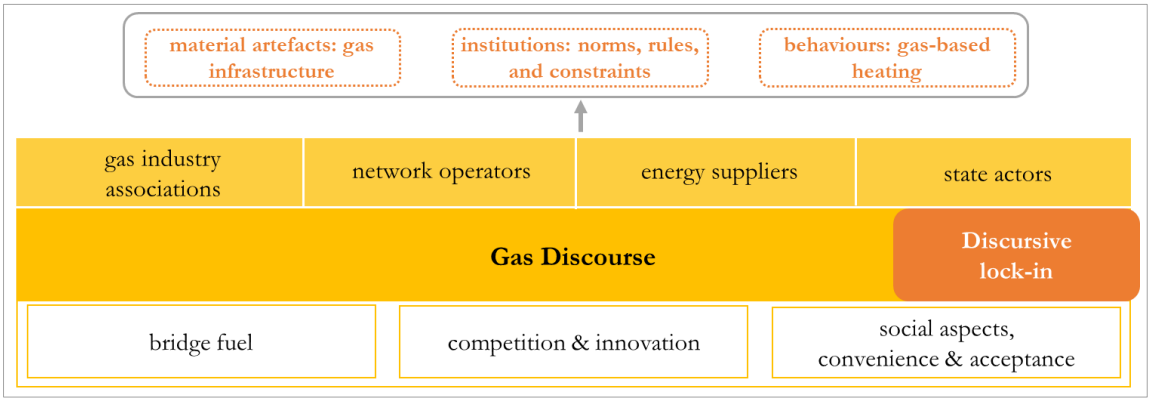

Figure 6-4. Discursive lock-in of institutionalised gas discourse
Source: Own presentation

The analysis of the interview and document data indicate that this is the case and a discursive lock-in at the regime level exists, as illustrated in Figure 6-4. The institutionalised gas discourse is quite dominant and supported by strong incumbent actors, allowing them to maintain the role of gas in the heating system. The regime actors have been successful in portraying gas as the central solution for the heat transition – both natural gas as a bridge fuel, as well as hydrogen as a future solution. As it has been highlighted in several interviews, it can be said that the strong discursive agency of regime actors allowed them to reproduce the institutionalised discourse more successfully than non-incumbents with a weaker agency can reproduce their discourse. For example, the *"strong influence of the gas lobby"* (Respondent 16, renewable heating industry association) has been referred to in several interviews. Thus, it is argued that there is an institutionalised mechanism of discursive reproduction which is built on the understanding that having natural gas as a bridge fuel is beneficial in the context of the German heat transition. This allowed both politicians, businesses, as well as heating customers, to make their decisions and actions based on that premise and to reproduce the discourse, without questioning it. It

could be observed that the discourse is predominant in societal and political discussions. For example, a respondent of an environmental NGO made the following observation: *"I think the public still perceives natural gas as a bridge technology. And even in the coalition agreement [of the new government], natural gas clearly still plays an important role"* (Respondent 11, environmental NGO). On the one hand, the respondent highlighted the perception of natural gas as a clean bridge fuel in society. This fact has been emphasised in several interviews: The regime actors were successful in manifesting their discourse in society and generating a positive image of natural gas. On the other hand, the respondent pointed out that in the coalition agreement of the new German government, it was referred to natural gas as an important bridge solution. This demonstrates that the discourse is dominant in the political landscape and shapes political action. Furthermore, the fact that the share of natural gas in the heating of buildings has not decreased within the last two decades – despite increasing academic knowledge about the negative climate impacts of natural gas – indicates that the gas discourse led to the stabilisation of the socio-technical system, i.e., a discursive lock-in, that is favouring natural gas.

Therefore, the discursive lock-in has contributed to the fact that the perception of natural gas within society and politics is still dominated by the clean bridge fuel narrative and the understanding that a phase-out of natural gas would not be realistic in the short term. The strong regime discourse has, in turn, consequences on infrastructure, behaviours, and institutions, and can lead to the reinforcement of carbon lock-ins. Thus, ultimately, this discursive lock-in is to some extent responsible for the large share of natural gas in Germany's heat system and the difficulties to accelerate the heat transition.

How the regime discourse affects infrastructure, behaviours, and institutions occurs in the following manner: Most importantly, a risk for an infrastructural lock-in has been identified, which is reinforced by the institutionalised gas discourse. An infrastructural lock-in can emerge, as due to the longevity of fossil infrastructures such as natural gas grids or the heating infrastructure within the buildings, changes to those carbon-intense pathways later might be costly or difficult. Thus, once the large infrastructure is installed, which is typically also connected with high initial investment costs, it will become more difficult to transition to alternative pathways. It is argued that there is a substantial risk for infrastructural lock-in in connection to natural gas. This has commonly been mentioned by the actors of the EDC, who highlight the large sum of investments in natural gas infrastructure and the connected risk that this might lead to infrastructural carbon lock-ins (Agora Energiewende, 2021; DUH & DIW, 2021; Respondent 11, environmental NGO; Respondent 14, environmental think tank). In addition, a self-reinforcing mechanism to resist change exists between infrastructure such as buildings and supporting infrastructure such as gas pipelines, as the supporting infrastructure usually cannot be readily used by other systems as they are built for a specific task such as transporting gas. Thus, the argument of needing to utilise the asset of the gas grid, as it entails large monetary value, could be used to justify the need to use natural gas in the buildings. For the building sector specifically, the risk of infrastructural lock-ins is especially high, due to the long investment cycles and longevity of building infrastructure. In addition, the variety of actors involved in decision-making about building technologies poses a challenge that potentially slows down change.
It is argued that this lock-in is reinforced by the discursive lock-in of portraying gas as the central solution for the heat transition. The regime actors portrayed the gas grid as an asset that should be utilised. For instance, it has been stated: *"The German gas network has a considerable worth. And we could convert it to hydrogen … This is an asset that I already have and that I should use"* (Respondent 4, gas industry association). By arguing that the natural gas grid could be converted to hydrogen, the incumbents aim to justify investments in the maintenance and expansion of the gas grid. The same counts for the infrastructure within the buildings: The respondents highlighted that the gas boilers would increasingly be 'H_2-ready' and could thus be switched to hydrogen in the

future (Respondent 8, gas network operator; Respondent 9, energy supplier). This argument was also used to justify the installation of natural gas-based heating boilers in the buildings. However, regarding the gas grid, it needs to be acknowledged that the gas infrastructure is not only used to transport gas for heating but also serves other sectors, as described in section 2.2. Therefore, it needs to be considered to which extent infrastructure will be needed in other sectors in the future to evaluate the extent of the infrastructural lock-in. Nevertheless, a lock-in of the gas infrastructure within or connected to the buildings can be identified in the context of this study.

Furthermore, the discursive lock-in might impact the creation of an institutional lock-in mechanism. Institutional lock-ins emerge as political, social, and economic actors involved in the system tend to reinforce a status quo trajectory that favours their interests and provides them with certain benefits. To achieve that, they intentionally and coordinated engage in efforts to impact institutional norms, rules, and constraints in their interest and defend those against a new status quo. It can be said that the regime actors within Germany's heat transition in the building sector actively try to defend the status quo of having natural gas-based heating by advocating for the gas discourse. For instance, the strong lobbying power of the gas industry has been highlighted, as well as their power to influence political and societal discussions. Furthermore, the large number of gas industry associations that loudly advocate for the gas discourse can be seen as a form of institutionalisation of the gas discourse. This form of institutionalised efforts helps the gas industry to defend their industry against the threats a heat transition would pose to them.

Lastly, behaviours are strongly influenced by discourses, and thus, a behavioural lock-in might be reinforced through the gas discourse. Behavioural lock-ins refer to the persistence of carbon-intensive behaviours. It is likely that the strong gas discourse of the incumbent regime actors has impacted behaviours in a way that justified the use of natural gas-based heating infrastructure. If heating with natural gas is portrayed as the norm, individual decision-makers likely follow that norm without questioning it and thus might decide to keep their gas-based heating systems. Likely, this is supported by some of the narratives of the gas discourse, that portray natural gas as cheap, comfortable, and convenient. This might have strengthened individual decision-makers in their choice of a gas-based heating system.

To sum up, the findings of the study show that a discursive lock-in at the regime level exists, which portrays gas as the central solution for the heat transition. This has contributed to the preservation of the large share of natural gas in Germany's heat system and the difficulties to accelerate the heat transition. Furthermore, the discourse, supported by strong incumbent actors, likely impacts the creation of infrastructural, institutional, and behavioural carbon lock-ins that lead to an entrenchment of the natural gas-based heating system.

6.2.2 Disruptive and Dynamic Discursive Change

Two current developments can be seen as 'windows of opportunity' for the heat transition that could lead to (discursive) changes. First, the shortages of gas supply resulting from the Russian war can be seen as a disruptive discursive change. Second, the increasing competitiveness and acceptance of heat pumps constitute a dynamic discursive change from within the socio-technical system. The discursive changes and their impacts on the discourses are visualised in Figure 6-5. Generally, it can be said that both discursive changes strengthen the electrification discourse and weaken the gas discourse. While the dynamic discursive change does not directly impact the meta discourse, the disruptive change has a direct influence and changes some basic assumptions of the meta discourse on the landscape level.

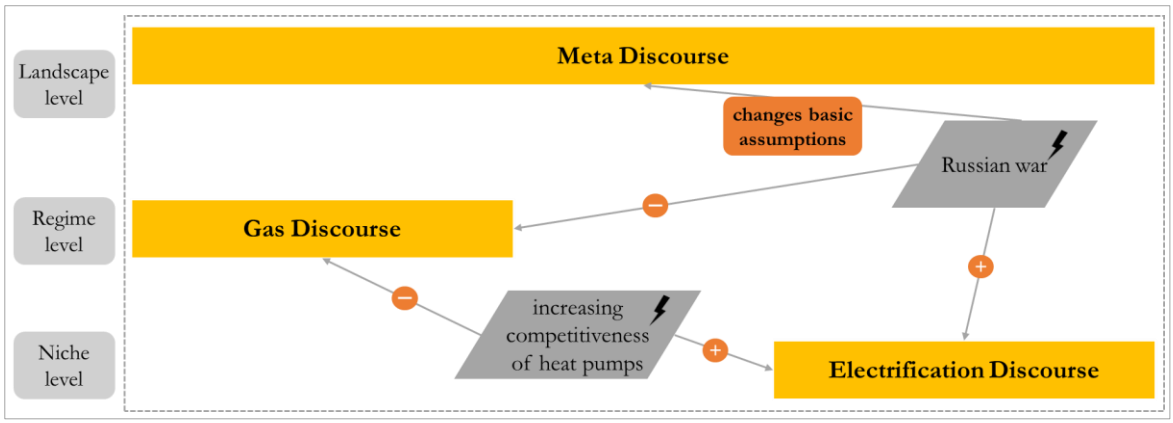

Figure 6-5. Disruptive and dynamic discursive change for the German heat transition
Source: Own presentation

A disruptive discursive change refers to a transformation based on exogenous events that change the values and assumptions at the meta level. This could be observed with the outbreak of the Russian war on Ukraine. In particular, the war has led to a new understanding of energy security and the negative consequences of fossil gas imports. While before the war, the topics of natural gas and energy security had not been on the public agenda, the war has sparked a public debate and has brought much attention to the topic of natural gas and its role in the German energy and heat system. Looking at the impacts the disruptive change has on the discourses, most importantly, it can be said that the outbreak of the war has challenged certain general assumptions of the meta discourse. As described in section 6.1.2, while the need for the heat transition was acknowledged within the meta discourse, there was a general understanding that there were various options on how to design that transition. In that respect, one assumption was that natural gas, in general, would be available as an import option for Germany. As natural gas has been a reliable, and in terms of its cost stable energy source, there was the assumption that, if no other decision was made, Germany would have the possibility to keep using natural gas. This has now changed drastically: The assumption that Germany can rely on natural gas imports is no longer secure. Actors have highlighted that there are large uncertainties among politicians, businesses, as well as private heat customers if natural gas would be available for them in the future. Thus, while beforehand they never doubted the availability of natural gas, now they have started understanding the risk of an insecure energy supply and started looking for alternative heat options. Thus, this could potentially lead to more acceptance and willingness of the society to act and contribute to the heat transition. Looking at the institutionalised and the alternative discourse, it appears that the gas discourse has been weakened, while the electrification discourse has gained strength. This is because the gas discourse was based on the assumption that natural gas would be available as a bridge fuel. Furthermore, the GDC portrayed natural gas as a cheap and convenient heating solution, which also changed with rising gas prices caused by the war. On the other hand, the electrification discourse was strengthened, as the renewable heating options are less dependent on imports and, according to the EDC, are seen as a more resilient and secure way for the heat transition. In general, the disruptive discursive change can be seen as an indicator that the institutionalised discourse might be challenged, and the socio-technical regime could be destabilised, providing a chance for the alternative discourse to gain ground.

Second, a dynamic discursive change stems from within the system, e.g., when alternative discourses are made attractive for incumbent actors and thus destabilise the institutionalised discourse. This could also be observed in the heat transition and the role of natural gas within that transition. The rapid emergence of heat pumps as a solution for the heat transition has

weakened the position of natural gas, which was beforehand often portrayed as the only alternative. In recent years, the knowledge about the suitability of heat pumps for various building types has increased. Furthermore, as they have been installed in an increasing number of buildings, it has been demonstrated that they are a viable solution, which has also led to an increased acceptance within society. At the same time, there has been an increasing awareness of the negative consequences of natural gas, as the problem of methane leakages has been detected. This can be seen as an indication that the gas discourse could slowly be weakened, providing a chance for the alternative electrification discourse to advance. While the dynamic discursive change is slower to achieve a change in the socio-technical system than the disruptive discursive change, it can still be of great importance for the acceleration of the transition, especially in combination with the disruptive change.

The fact that, at the moment, both a disruptive and a dynamic discursive change can be observed within Germany's heat transition in the building sector can be seen as a great chance to accelerate the transition, as the changes are mutually reinforcing. The disruptive change causes more attention and is perceived as a bigger disruption, as some general assumptions are challenged. However, while it causes attention, it does not necessarily offer a solution to the question of how the discourse should change. This is what the dynamic change offers: By strengthening the alternative discourse, the dynamic change provides an option for the transition away from the socio-technical regime that was predominant before. Thus, it is the interplay of the two discursive changes that has the potential to cause a transition. Therefore, currently, there is a chance to challenge the institutionalised gas discourse at the regime level, advance the alternative electrification discourse and push for renewable heating solutions. This can be seen as momentum to accelerate the German heat transition in the building sector.

7 Discussion

This chapter seeks to discuss the findings of this thesis. First, the two discourses are critically reflected on, focusing on their proposed pathways for the German heat transition. Thereby, the first section of the discussion chapter aims to scrutinise the content of the discourses and compare them to the findings of energy transition studies for the German context. This allows for gaining deeper insights into the underlying strategies of the coalitions' discourses. Subsequently, the academic contribution of this work and the significance of the findings are demonstrated by comparing them back to already existing literature, showing how the findings addressed the identified research gaps. Furthermore, the limitations of the work are discussed.

7.1 Critical Reflection on the Discourses

This section summarises the main differences between the assumptions and statements between the GDC and the EDC about the role of natural gas in Germany's heat transition in the building sector, and critically reflects upon them. While in chapter 6, the discourses were described, this section scrutinises their content by comparing them to existing knowledge on the German heat transition. Table 7-1 provides an overview of the main discussion points. The aspects included in the table constitute the most striking differences between the two discourses concerning how they envision Germany's heat transition in the building sector. This is set in context to the energy transition studies for Germany, as described in the background section (section 2.3.2) and academic literature (chapter 3). Thereby, this section aims to shed light on some of the aspects that have been discussed with a great contradiction between the two coalitions, and to create an understanding of to what extent the arguments are backed up by scientific knowledge. While a comprehensive evaluation of the arguments made would be out of the scope of this thesis, this section aims at providing some clarity about some of the arguments made by the coalitions, especially in the cases where they diverged from one another. Moreover, by demonstrating how the two discourses' arguments and proposals align or diverge, respectively, from the findings and recommendations of scientific studies, this section reflects on the intentions behind the usage of such arguments.

Table 7-1. Comparison between institutionalised and alternative discourse

Topic	GDC	EDC
Phase-out of natural gas	unrealistic in the short-term	as soon as possible, the latest from 2025 on
Role of heat pumps	increasingly important, but not suitable for all building types	main solutions for many buildings, independent of refurbishment status, refurbishment of buildings will be needed in any case to meet climate targets
Role of hydrogen	important for the heating of buildings, will replace natural gas will be available in sufficient amounts in the future and become increasingly competitive	should not be used in the heating of buildings except for a few exceptions; electrification is more efficient for heating costs, potential, environmental impacts, and technical feasibility of hydrogen are uncertain
Gas infrastructure	will be needed probably to the same extent, as it will be switched to transporting hydrogen	decommissioning especially of smaller distribution grids will be necessary; switching to hydrogen will require large adjustments to infrastructure, and costs are yet unknown
Political solutions	support for the development of a hydrogen infrastructure most crucial strict regulative measures not favourable	clear strategy for exit from natural gas should be prioritised financial, regulative, and communicative incentives for the uptake of renewable heat

Source: Own presentation

First, the proposed electrification pathway of the EDC is generally more aligned with energy transition studies for the German context in highlighting the need for a fast *phase-out of natural gas* (dena, 2021b; Prognos et al., 2021). For instance, the study 'Climate neutral Germany 2045' proposes that from 2025 on, gas- and oil-based heating systems should only be installed in a few exceptional cases (Prognos et al., 2021). This supports the demands of the EDC. The GDC, in contrast, argues that a fast phase-out will be unrealistic due to the major challenge of a roll-out of renewable energies and the specific challenges of the building sector that do not allow for a fast transition, and is opposed to having a clear phase-out. The challenges of the heat transition in the building sector brought forward by the GDC, such as the heterogeneity of the German building stock, are also highlighted in academic literature (Engelmann et al., 2021; Frank et al., 2020; UBA, 2020a; Weiß et al., 2018). However, literature also finds that clear phase-out strategies help to address those challenges, e.g., by reducing uncertainty for the building managers (Weiß et al., 2021). Therefore, it is argued in this thesis that while the challenges need to be addressed and solutions for all buildings need to be found, in general, a clear phase-out strategy for natural gas should be developed. It could be assumed that the GDC sees the clear phase-out as a threat to the industry. By advocating for a later and slower transition, they might aim to prevent a strict phase-out and thereby keep gas in the heating of buildings for longer.

Second, the EDC aligns with the German energy studies, as described in section 2.3.2, in focusing especially on *heat pumps*, but also decarbonised heat networks. The topic of heat pumps has been discussed more controversially between the two coalitions than heat networks, therefore, the following section focuses on heat pumps. The energy studies of the German Energy Agency (dena, 2021b) and leading research institutes (Prognos et al., 2021), as well as the EDC, argue that a high increase in the uptake of heat pumps will be crucial to reaching Germany's emission reduction goals in the building sector. The importance of heat pumps for the German heat transition has also been demonstrated in multiple academic studies (Bernath et al., 2019; Gaur et al., 2019; Hilpert, 2020; Merkel et al., 2017; Sterchele et al., 2017). In contrast, the GDC continuously mentioned that heat pumps would only be a feasible option for a limited number of building types and not a solution for the broader building stock. In line with that, several studies have previously found that the energy efficiency of heat pumps varies between heat pumps operating in older, un-refurbished buildings and in newly constructed buildings with surface heat distribution, making heat pumps the more obvious solution for new buildings (Huchtemann & Müller, 2012; Miara et al., 2017). However, more recent studies have emphasised the improved technical feasibilities as well as increased experience with the installation of heat pumps, making heat pumps suitable for various building types (Energy Systems Catapult, 2022; Mellwig et al., 2021). Studies from the UK and Germany, for instance, highlighted that heat pumps can be suitable for various building types, regardless of their age or refurbishment status, or that minor adjustments in existing buildings are often enough to operate a heat pump efficiently (Energy Systems Catapult, 2022; Mellwig et al., 2021). While it needs to be acknowledged that further research would be beneficial to better understand the technical and practical feasibility of a large-scale rollout of heat pumps into the German building stock, in general, the prospects of heat pumps are, according to literature, likely more positive than they are portrayed by the GDC. Importantly, some prerequisites need to be fulfilled for heat pumps to reach their full environmental benefits, most crucially, the increase of renewable energies in the electricity mix (Bockelmann & Fisch, 2019; Huchtemann & Müller, 2012; Sterchele et al., 2017). This has not always been acknowledged by the EDC, which might be considered an attempt to avoid drawing attention to the challenges of electrification, in order to maintain electrification as the best way to move forward. On the other hand, portraying heat pumps as unsuitable for the wider building stock of Germany could be seen as a strategy of the GDC to defend gas-based heating from the threat of electrification. The topic of heat pumps came up frequently during the interviews with the GDC, and the interviewees mentioned that heat pumps had a bad image within society and were mostly a solution only high-income

households could afford for their newly built houses. This could be seen as an indicator that to some extent, the incumbents are trying to make heat pumps seem to have less potential than they have or, according to literature, could have in the future. As the energy transition studies for the German context count on a large roll-out of heat pumps and a decrease in gas-based heating (dena, 2021b; Prognos et al., 2021), this could be seen as a threat to the GDC, and by trying to make the electrification option seem to be less suitable, the role of gas could be defended.

Third, the role of *hydrogen* in the heating system is portrayed in a contradicting way between the two coalitions. The GDC considers hydrogen to play an important role in the heating of buildings. They expect hydrogen to be increasingly available and affordable in the future and portray the transformation from natural gas to hydrogen as the least disruptive, cheapest, and easiest transition pathway. Therein, the GDC considers the availability of hydrogen to be higher than estimated in most of the currently available studies (Hainsch et al., 2020; Prognos et al., 2021; Wachsmuth et al., 2019). Besides, most of the academic studies on hydrogen highlight the large uncertainties around the availability and potential of hydrogen. Lowes et al. (2020), for instance, demonstrated the uncertainty around the carbon reduction potentials, as well as the availability and costs of hydrogen. In addition, due to the lack of real-world experiences, the technical uncertainty around hydrogen has been highlighted: This refers to, e.g., the technical feasibility of carbon capture and storage potentials (Middleton & Yaw, 2018), the development of appliances to burn hydrogen, the suitability of pipework, and the safety of hydrogen (Lowes & Woodman, 2020). Furthermore, studies also highlight that if hydrogen would be available in the future, it will be needed more urgently in other sectors, such as heavy industry and transport (Hainsch et al., 2020; Wachsmuth et al., 2019). Therefore, most of the leading energy scenario studies in the German context also do not consider substantial amounts of hydrogen in the heating of buildings (dena, 2021b; Prognos et al., 2021; Wachsmuth et al., 2019). There is a general agreement that in most cases, electrification options will be more efficient for the heating of buildings and should be prioritised (Hainsch et al., 2020; Wachsmuth et al., 2019). It can be said that the demands of the EDC are generally more aligned with current literature concerning the role of hydrogen in the heating of buildings. The actors of the EDC highlight the large uncertainties around hydrogen, as also demonstrated in the literature (Lowes et al., 2020; Middleton & Yaw, 2018; Strbac et al., 2018). Furthermore, the EDC argues that hydrogen should only be allowed for a few exceptions, and in general, electrification options are more efficient and should be prioritised, which is in line with the energy transition studies for Germany (dena, 2021b; Prognos et al., 2021).

Connected to the discussion around hydrogen in the future heating system of buildings is the *need for gas infrastructure*. In line with the assumed decrease in the use of gas and the exclusion of hydrogen for the heating of buildings, the EDC argues that especially smaller gas distribution grids will not be needed in the future and should gradually be decommissioned. Investments into gas infrastructure would most likely lead to stranded assets in the future, as the switch to hydrogen would be difficult and require large and likely expensive readjustments of the grids. Studies on the future gas grid also estimate that the need for gas infrastructure will decline, which supports the claims of the EDC (Giehl et al., 2021; Kusch et al., 2012). For instance, Giehl et al. (2021) found that there will be a declining need for gas distribution networks in different scenarios, even in scenarios with a high percentage of synthetic gases in the heating system. In contrast, the GDC supports the maintenance and expansion of the gas grid and argues that it will be possible to repurpose the gas infrastructure for the use of hydrogen. In that regard, literature has pointed out that due to the lack of practical hydrogen conversion projects, all statements about the costs of transforming the heating system to include hydrogen are mere estimates with great uncertainty (Lowes et al., 2020). In general, no independent studies could be identified that examine the technical possibility and the potential costs of repurposing the

natural gas infrastructure for the use of hydrogen. From this, it could be argued that the continuous support for the expansion of the gas infrastructure as proposed by the GDC could be seen as an indicator of the GDC trying to defend the assets they have in form of infrastructure, as well as the status of the gas industry in the future heating system. As they might consider switching their operations from natural gas to hydrogen, a heat transition that includes hydrogen would be in their favour. However, considering the large uncertainties, the risk to create stranded assets, and the urgency to accelerate the heat transition, this option seems not to be suitable to meet the challenges of the German heat transition.

Lastly, the differences in assumptions between the two coalitions also impact the *political solutions* they propose. The GDC argues that the support for the development of a hydrogen infrastructure would be most important for the German heat transition, and they are against strict regulative measures that would lead to the phase-out of natural gas. Oftentimes, the actors brought up the argument of free economic competition and innovation when arguing against strict policy measures. Instead, the GDC advocates for allowing all kinds of energy carriers and technologies in the mix, creating a situation where it is most likely that the currently dominant technology will maintain its dominance, as new technologies would require regulatory support to establish themselves. When looking at literature, experience from other countries has shown that regulative measures are most successful and needed for phasing out fossil fuel-based heating: For instance, Weiß et al. (2021) found that the regulatory phase-out of fossil-fuelled boilers like it has been done in Denmark can be an example for Germany. The authors further state that due to the widespread use of natural gas, renewable energies in buildings will not increase due to price incentives like raising taxes on fossil fuels alone, but rather, regulatory measures are needed. The EDC is in favour of strict policy measures that lead to a phase-out of fossil fuel-based heating, as well as regulative, financial, and communicative instruments to increase the uptake of renewable energy in the heating of buildings. The actors of the EDC argue that since the pathway for achieving climate neutrality is so narrow, heating solutions that are proven to work efficiently need to be prioritised, and thus, they consider the support of heat pumps and decarbonised heat networks to be crucial. Therein, they follow, e.g., the suggestions of Schrems et al. (2021), that developed a roadmap for a phase-out of natural gas in the building sector. Furthermore, the supported measures of the EDC are generally more aligned with the pathway outlined in the German energy transition studies (dena, 2021b; Prognos et al., 2021).

This section has scrutinised the suggested pathways of the respective discourses and has set them into the context of current literature on the German heat transition. Furthermore, the section has reflected upon potential strategies of the coalitions behind pushing for certain solutions. In general, the EDC tries to push for the uptake of renewable heating solutions and the GDC tries to defend the role of gas in Germany's heating system, and both coalitions aim at portraying their respective solution as the best pathway for Germany's heat transition. In that regard, it can be noted that in both coalitions, there are actors with business interests that want to align the transition with their respective economic motivations. However, it was observed that the actors of the EDC are in general found to have less economic interest in their pursued strategy, as the EDC is largely made up of environmental NGOs and research institutes. Furthermore, the EDC generally tends to be more aligned with current literature on the heat transition. In contrast, some of the arguments of the GDC are deviating from existing literature, e.g., when it comes to the feasibility of heat pumps, or the potential of hydrogen. Instead, the proposed strategies might be oriented towards the interests of the gas industry, as they often coincide with maintaining gas as a relevant heating solution. Based on these findings, it is argued that to some extent, the GDC aims at protecting the gas industry and the role and significance of gas-based heating against the threat of electrification.

7.2 Discussion and Significance of Findings

This section discusses the relevance and the academic contribution of this thesis. After demonstrating how the findings of this thesis addressed the identified research problem, the significance and academic contribution from a methodological and conceptual point are discussed. Finally, the findings are compared to current literature, showing how they relate to already existing knowledge, and how they provide new insights.

This thesis adopted a constructivist approach to transition research, by focusing on narratives and discourses within the German heat transition in the building sector. Thereby, it produced useful knowledge that contributes to addressing the research problem that had been identified: the urgent need to decarbonise the heating of buildings to stay in line with emission reduction targets, and the stagnating heat transition with a continuously high share of fossil-based heating. There had been a lack of knowledge of the narratives used, and the discourses they feed into, around the role of natural gas in the heat transition and the implications they might have, especially considering the risk of carbon lock-ins. By identifying and dismantling those narratives, this thesis has provided a deeper understanding of the underlying dynamics of the heat transition and an explanation for the ongoing support for natural gas despite its well-known negative climate impacts. This thesis has demonstrated that the dominant gas discourse has led to the creation of a discursive lock-in that has the potential to hinder the expansion of renewable heating technologies. Yet, by demonstrating the significance of discursive changes, this thesis pointed out a window of opportunity to act and accelerate the heat transition.

Significance of Methodological and Conceptual Approach

From a methodological and conceptual point of view, the findings of this thesis demonstrated the value of taking on a constructivist and interpretative approach to transition research and focusing on the role of narratives and discourses. Therein, this work aligns with existing research in the field (Rosenbloom et al., 2016; Simoens et al., 2022). On the one hand, the usefulness of constructivist or interpretative approaches for understanding change has been shown. It has been explained how discursive changes can constitute a window of opportunity to stimulate change. In the case of this thesis, the findings indicated that changes in the discourse, as they, for instance, occurred as a consequence of the outbreak of the Russian war, have the potential to stimulate change. This supports, e.g., the findings of Kern (2011), who argued that change occurs when new discourses challenge existing institutions, or Hermwille (2016), who found that narratives are helpful to developing an understanding of how policy responses to exogenous changes in the environment have influenced transformation processes. On the other hand, the findings support the claim that the analysis of discourses can help to understand the prevention of change, e.g., if incumbents try to defend their regime (Pesch, 2015) or to align the transition to their interests (Bosman et al., 2014). This has also been demonstrated within this study, as scrutinising discourses has led to an understanding of how incumbent actors of the gas discourse coalition try to defend their regime. It has been shown that the GDC has been successful in portraying gas as the central solution for the German heat transition, creating a discursive lock-in that has the potential to prevent the acceleration of the heat transition.

Furthermore, this thesis has demonstrated the value of analysing discourses and narratives to understand carbon lock-ins. Discourses have the potential to create or reinforce carbon lock-ins, but also to stimulate change. This aligns with the findings of Buschmann and Oels, (2019), who highlight the overlooked role of discourses in analysing carbon lock-ins. Looking at the German energy transition, they found that discursive turning points were important for overcoming carbon lock-ins. This thesis adds to their findings in multiple ways: First, the focus on the heat transition in the building sector and specifically on natural gas offers insights specifically for that sector. More specifically, this thesis has demonstrated that there is a

particular risk in the building sector for carbon lock-ins due to the longevity of the building infrastructure. Besides, the diverging discourses in the building sector can lead to uncertainty for the various actors involved, which is why politicians should focus on reducing that uncertainty by developing a clear strategy for the heat transition. Second, more recent events were considered, which allowed, e.g., for the identification of further possible discursive turning points. Especially the implications of the outbreak of the Russian war on the discourse around natural gas constitute novel findings.

Lastly, this study is significant in its development and operationalisation of a conceptual framework focusing on discursive transition studies, narratives, discourses and discursive lock-ins, as well as discursive change. Thereby, this thesis adds to the study by Simoens et al. (2022) which provided the basis for the framework that has been further elaborated within this thesis. Simoens et al. (2022) criticised that a structured exchange between interpretative discourse analysis in the field of environmental policy and transition research had been lacking, which limited the understanding of the role of discourses in sustainability transitions. Therefore, they developed a heuristic framework linking environmental discourse and sustainability transition research. While their work provides the theoretical basis, this thesis offers a practical application by utilising the framework to analyse the German heat transition and the role of natural gas. Furthermore, the framework has been elaborated to include the concepts of narratives and discourse coalitions. This constitutes a key contribution of this thesis.

Significance of the Content

With regard to the findings, this thesis provided significant knowledge in identifying and dismantling the most prominent narratives concerning natural gas in Germany's heat transition in the building sector. While the literature review resulted in the identification of several studies examining the narratives around natural gas, an analysis of the narratives about the role and significance of natural gas within the heat transition in Germany was not found. Nevertheless, some common findings can be highlighted that mirror previous studies. Most prominently, the literature pointed out the 'bridge fuel narrative' about natural gas, portraying it as the least harmful fossil fuel and thus suitable for quick decarbonisation within energy transitions (Delborne et al., 2020; Howarth, 2014; Stephenson et al., 2012; von Hirschhausen et al., 2020). This could be confirmed within this study, as the bridge fuel narrative was most used by the GDC. On the other hand, the findings of this thesis also support the claims of other studies in stating that the bridge fuel narrative is being contested, and, e.g., a new narrative of the need for a natural gas exit is emerging (von Hirschhausen et al., 2020).

In addition, this thesis agrees with previous authors in demonstrating that currently, there is a risk to create carbon lock-ins concerning natural gas and therefore miss Germany's climate targets, besides making the heat transition more expensive due to stranded investments (Brauers, Braunger, Hoffart, et al., 2021; Brauers, Braunger, & Jewell, 2021; Fitzgerald et al., 2019). In both the studies by Brauers, Braunger, & Jewell and Fitzgerald et al., the authors highlight that incumbent actors involved in the discussion around natural gas play a prominent role in creating the lock-in effect and shaping the discussion in line with their interests. This thesis is consistent with those findings by demonstrating that the strong discursive agency of the regime actors allowed them to create a discursive lock-in of portraying gas as the central solution to the heat transition. However, in contrast to the studies by Brauers, Braunger, & Jewell and Fitzgerald et al., this thesis has focused on the building sector specifically and not on natural gas in general. Thereby, this thesis was able to highlight the particular risk of creating carbon lock-ins in the building sector due to the longevity of the building technologies, and the challenges the building sector entails like the variety of actors involved in decision-making.

Furthermore, this thesis supports the findings of other studies in demonstrating the important role of incumbent regime actors and the discourses they pursue in shaping energy transitions. The findings of this thesis align with Stephenson et al. (2012), that highlight that the transition fuel label can be used to legitimise carbon-intensive gas development. This mirrors the risk of a discursive lock-in that has been identified in this study, as the prominent gas discourse is utilised to justify and legitimise the continuous use of natural gas. In addition, this thesis has pointed out that incumbent regime actors of the gas coalition often referred to hydrogen as a substitute for natural gas in the heating of buildings. It has been argued that this framing is used to strengthen the bridge fuel narrative and defend the role and status of the gas industry, as well as to form the heat transition in line with their interests. These findings are similar to the ones of Lowes et al. (2020) that analysed the influence of incumbent discourse coalitions on the transformation of the heating system in the UK. They also found that a strong pro-gas discourse coalition is trying to defend the threat of electrification by promoting a decarbonisation pathway based on replacement gases, despite the uncertainty around their potential. Furthermore, the strategy of incumbents to promote a hydrogen-based transition has been analysed by Szabo (Szabo, 2021b). The author found that by portraying alternative gases as a feasible solution for the energy transition, incumbents try to shift the focus away from the uncertainties around the potential of these alternative gases and detract from the importance of electrification. Indications for this claim have also been identified within this study. However, it also needs to be acknowledged that an analysis of hydrogen and other replacement gases, as well as the narratives around them, have not been the focus of this study, and thus, further research would be needed to confirm the findings.

Lastly, the findings of this thesis are of significance as they capture some of the reactions to the recent political developments in connection with the Russian war on Ukraine and the implications for Germany's energy system. As interviews have been conducted right after the outbreak of the war, data collection was impacted by the developments. While the results mirror short-term reactions by the actors in this extreme situation, further research is needed to capture the middle- and longer-term consequences and evaluate the political and societal reactions. However, in this study, it has been demonstrated with the identification of a disruptive discursive change, that the war has brought a lot of attention to the high share of natural gas in Germany's energy mix and the negative consequences of fossil fuel dependencies. The interviewees highlighted the increased awareness and interest in the topics and perceived a higher willingness amongst politicians and society to act. The fact that this change has direct influences on policy action has also become clear, with the German government putting the gas pipeline 'Nord Stream 2' on hold and agreeing to the construction of LNG import terminals. The necessity of those LNG terminals is currently widely discussed, with opponents emphasising the risk to create carbon lock-ins. However, an analysis of those developments is out of the scope of this thesis. In any case, and as it has also been announced by the German government, the fast expansion of renewable energy must be in focus.

7.3 Critical Reflections and Limitations

This thesis has several limitations that need to be considered. First, the results of this thesis are limited in their *reliability*. Reliability in qualitative research refers to the consistency of the researcher's approach and the degree to which a study can be replicated, which can generally be increased by providing detailed information about the procedures and methods employed in a study (Bryman, 2012; Creswell & Creswell, 2017). While this was attempted in this study and the methods for data collection and analysis are thoroughly described, reliability is constrained by confidentiality agreements that do not allow for the disclosure of personal names and organisations. Furthermore, a constraint for reliability can be seen in the use of semi-structured interviews and allowing for variation in the type of questions asked depending on the interviewee. While this allowed for more tailored questioning and going into details about the

topic of interest for the research, structured interviews could have led to more reliable results. However, gaining a deep understanding and obtaining rich data was prioritised in this case. Furthermore, it was attempted to increase the reliability by always providing the same introduction and asking some common questions across all interviews, and by using NVivo to perform a systematic thematic analysis.

Furthermore, the results of this thesis are limited in their *external validity*, meaning the degree to which findings can be generalised (Bryman, 2012). Contextual factors of Germany's heat transition in the building sector at the specific timeframe considered in the study have influenced the study results, and thus, the findings are not valid for different geographical or time scopes. Moreover, the specific contextual factors of the particular actors that have been included in the analysis have most likely influenced the results. In that respect, it is important to highlight that the results are only valid as an analysis of the data included in this study and cannot be generalised. However, this is in line with the intent of qualitative research in general, as the goal is usually not to generalise findings (Creswell & Creswell, 2017).

Moreover, *internal validity* needs to be considered, which refers to the internal accuracy of the findings based on the methods employed and data collected (Creswell & Creswell, 2017). Data source triangulation was performed to increase internal validity. The use of multiple data sources (interviews and documents) contributed to gaining a more comprehensive understanding of phenomena (Nancy Carter et al., 2014). However, due to the time constraints of a master's thesis, it needs to be considered that only a limited number of interviews could be conducted, and a limited number of documents could be reviewed. Thus, including more data sources in the analysis would increase the internal validity of the findings. Furthermore, interviews contain the risk of reproducing personal views rather than revealing data which is representative of a whole actor group. This could have been accounted for more strongly by including more documents. This is also connected to the bias the researcher brings to the study. Especially while conducting interviews, there is a risk of subconsciously influencing answers and nudging respondents into desired answers. Thus, the researcher's worldview inevitably shaped the data collection and analysis.

Some further limitations can be reflected upon. First, there are some limitations regarding actor selection and actor grouping. By basing the actor selection largely on the analysis performed in other studies and the identification of actors that are prominent in the debate, there is a risk to oversee actors with smaller discursive agency and fewer resources to make their voices heard. Moreover, by grouping individuals into actor groups and subsequently into coalitions, nuances between the individual actors and between the actor groups get lost. While actor groups might be allocatable to one discourse, differences between the actors might still exist, which do not get caught when relying on the concept of discourse coalitions. Nevertheless, the grouping allowed for a more manageable data analysis process and for focusing on the big picture, rather than on details.

Second, one limitation is seen in the fact that while the analysis was performed in English, data collection, i.e., the interviews as well as analysed documents, was conducted in German. Thus, slight nuances of the meanings expressed through the use of language and wordings might have been lost in translation. An attempt to counterbalance this limitation was through a thorough review of commonly used translations in other scientific publications, and/or through the disclosure of both the English and German words or phrases.

Third, the scope of the study limits the findings in several ways. For instance, focusing only on the building sector and excluding other sectors natural gas is used in poses a challenge to the analysis. This is especially relevant for the discussion of infrastructural lock-ins, as the gas

infrastructure is used for multiple sectors. Thus, strictly distinguishing what part of that infrastructure is used for the heating of buildings and what part for the other applications is not possible, and synergies between the different sectors exist that influence the need for gas and gas infrastructure. In addition, limiting the scope within the building sector to natural gas, and only marginally discussing alternative heating options, including heat pumps and heat networks, or alternative gases like hydrogen or biogas, restricts the findings. It is unusual for transition studies to focus on one specific energy carrier within one specific sector, i.e., natural gas in the building sector in this case, but instead, most studies have a more holistic approach. This potentially limits the results of the study as the interlinkages of energy systems make the isolated analysis of one aspect difficult. On the other hand, it allowed for a more detailed and specific assessment to understand the particular role of natural gas within the building sector's heat transition.

8 Conclusions

This chapter concludes the thesis by providing answers to the posed RQs and summarising the main findings. Furthermore, practical implications and recommendations are discussed, as well as academic implications in form of suggestions for further research.

8.1 Conclusion and Answers to the Research Questions

This thesis had the general aim to add to the understanding of how Germany's heat transition in the building sector can be accelerated. The fact that natural gas constitutes such a large share of Germany's heating of buildings over decades without decreasing its share, despite the increasing knowledge about its negative climate impacts and the risk of carbon lock-ins, raised the question of where the ongoing support comes from. Furthermore, reasons were sought for the fact that the heating of the building sector is only transforming slowly and marginally, even though ambitious climate targets require rapid decarbonisation of buildings. It was suggested that taking on a constructivist approach and analysing narratives and discourses might shed light on the underlying dynamics of the heat transition. There was a lack of knowledge of the narratives used, and the discourses they feed into, around the role of natural gas in the heat transition and the implications they might have, especially considering carbon lock-ins.
This thesis has demonstrated that narratives and discourses can be a useful tool to gain a deeper understanding of the heat transition. Furthermore, it was shown that discursive lock-ins can potentially prevent the dissemination of renewable heating technologies and thus slow down the transition. Yet, discursive changes might also provide windows of opportunity for change.

First, answering RQ1 and RQ1a, this thesis has identified and dismantled narratives that are commonly used to describe the role and significance of natural gas in Germany's heat transition in the building sector and have allocated those narratives to discourses.

RQ1: *Which narratives are commonly used to describe the role and significance of natural gas in Germany's heat transition in the building sector?*

> ***RQ1a:*** *Which discourses do the narratives feed into?*

This thesis has shown that there are two prominent discourses around natural gas in the heat transition in the building sector: The electrification discourse coalition is advocating for a phase-out of natural gas and the expansion of electricity-based heating, and the gas coalition is trying to defend the role of natural gas. Besides, both coalitions share the narrative of the need to reach Germany's climate targets, which demonstrates that the topic of climate change has reached the meta level discussion, independent of the actor coalition.

The gas discourse has been identified to be the institutionalised discourse at the regime level, due to the strong discursive agency of its proponents, the dominance in public and political discourse, and the overarching share of gas-based heating. The GDC is utilising various narratives with the main goal to defend the status of natural gas in the heating system, and, increasingly, push for the allowance of alternative low-carbon gases in the heating of buildings. The first narrative, the bridge fuel narrative, is strengthened by this vision to include alternative gases in the heating of buildings, as it is argued that the transition from natural gas to alternative gases is the easiest, least disruptive, and cheapest pathway, especially because natural gas infrastructure could be adjusted for hydrogen. Furthermore, the bridge fuel narrative tells the story of natural gas being the best way of achieving fast emission reductions in the building sector, especially because renewable energy solutions are not ready, and their potential is in general limited. The second narrative is centred around free competition and innovation: The GDC argues that an approach that does not give preference to certain technologies

('Technologieoffenheit') should be preferred as then competition will lead to lower prices and innovation will emerge. This can be seen as an attempt to prevent strict regulative measures and defend the role of natural gas in the heating market. Lastly, the narrative of natural gas being the most social, convenient, and thus most accepted heating solution supports the gas discourse.

The alternative electrification discourse is advocating for the expansion of electricity-based heating, especially heat pumps, and decarbonised heat networks. They strongly argue for a phase-out of natural gas as soon as possible, based on several narratives. First, the climate change narrative is dominant in the EDC's framing, and often, a reference to the risk of methane leakages is made. The negative climate impacts of natural gas especially considering methane leakages have only recently gained awareness – this is seen as a partial explanation of why the 'clean bridge fuel' narrative has been so successful. Second, the narrative of energy security and resilience emerged as a reaction to the Russian war, which shed light on the dangers of the high dependency on energy imports. This, according to the EDC, strengthened the case for an electrification pathway for the heat transition. The last narrative that has commonly been mentioned by actors of the EDC is the risk of creating carbon lock-ins or stranded assets by relying on natural gas in Germany's heat transition. As a phase-out of natural gas should be envisaged, investing in gas infrastructure should be avoided, especially having the longevity of the gas grid and building heating technologies in mind.

The two discourses have been critically discussed and compared to current knowledge on the German heat transition. On that basis, it has been argued that the narratives of the GDC are largely aimed at protecting their industry and the role and significance of gas-based heating against the threat of electrification.

Second, this thesis has revealed some likely implications the identified narratives and discourses have on the German heat transition, answering RQ2.

RQ2: *What are the potential implications of the narratives and discourses regarding the role of natural gas for the German heat transition in the building sector, especially considering lock-in effects?*

It has been shown that narratives and discourses, to some extent, can have an impact on the heat transition. On the one hand, discourses can lead to discursive lock-ins that can partially explain the prolonged support for natural gas-based heating in Germany's buildings. On the other hand, discursive changes have the potential to accelerate change.

A discursive lock-in has been identified at the regime level: The dominant gas discourse has allowed the regime actors to portray gas as the central solution for the heat transition. It has been observed that the institutionalised discourse has largely been reproduced and thereby justified and constituted the institutions, behaviours, and infrastructures of the natural gas-based heating system. This has led to the basic understanding of having natural gas as a bridge fuel makes sense in the context of the German heat transition, and has, in turn, influenced the perception and discussion across society and within politics. The regime actors were successful in manifesting their discourse in society and generating a positive image of natural gas. Furthermore, e.g., the bridge fuel narrative is still present in political debates, which shows that the gas discourse is also reproduced at that level. Furthermore, the continuous high share of natural gas in the heating of buildings despite the increasing academic knowledge about the negative climate impacts of natural gas can be seen as an indicator that the gas discourse led to the stabilisation of the socio-technical system, i.e., a discursive lock-in, that is favouring natural gas. Therefore, the argument is made that a discursive lock-in of the gas discourse can to some extent explain the large share of natural gas in Germany's heat system and the difficulties to accelerate the heat transition.

In turn, the discursive lock-in potentially has consequences on material artefacts, behaviours, and institutions and can add to the creation or reinforcement of carbon lock-ins. There is a significant risk of creating an infrastructural lock-in with regards to natural gas in the building sector, due to ongoing investments in gas infrastructure that will likely not be needed to the same extent in the future. Second, an institutional lock-in is likely to emerge, as institutions have engaged in efforts to reinforce the status quo trajectory, i.e., natural gas-based heating, by impacting institutional norms, rules, and constraints. Lastly, behaviours have been impacted and a behavioural lock-in is likely as people perceive heating with natural gas as the norm. Thus, there is the risk that these lock-ins slow down the heat transition and climate targets will be missed.

Yet, two current developments have been identified as 'windows of opportunity' for the heat transition that could lead to (discursive) changes. The outbreak of the Russian war has disruptively changed the understanding of energy security and the negative consequences of fossil gas imports and thus challenged some basic assumptions. The large uncertainties around the secure supply of natural gas have caused increased attention across society, which could cause a higher willingness to look for alternative heating options. Second, the increasing competitiveness of heat pumps stimulated a dynamic discursive change. Renewable heating options like heat pumps are continuously gaining market share and attention, while negative consequences of the use of natural gas become more prominent with more research, especially on methane leakages. Thus, in consequence, alternative heating options might gain ground, while natural gas-based heating loses importance. Due to the dual, mutually reinforcing discursive changes, with the disruptive discursive change bringing a lot of attention to the role of natural gas, and the dynamic discursive change strengthening the alternative discourse and thus providing a sense of direction for the transition, great momentum is seen to accelerate the German heat transition in the building sector.

8.2 Practical Implications and Recommendations

This thesis has high practical relevance for policymakers advancing the heat transition in the building sector, practitioners like NGOs working on advancing the energy transition, businesses involved in energy production and distribution and heating technologies, as well as end customers. Most importantly, all actors profit from an understanding that dominant discourses do not necessarily portray the pathway that is most preferable from an environmental, or most feasible from a political and technical perspective. Instead, actors should critically reflect on prevailing discourses before reproducing them, as otherwise, discursive lock-ins will be reinforced.

From a *policy perspective*, there is an urgent need to come up with detailed plans and policies on how the heat transition in Germany's building sector can be facilitated to stay in line with climate agreements and emission reduction goals. This thesis has shed light on the discussion around natural gas in the building sector and therefore can help policymakers to gain a deeper understanding of the heat transition and the interests of the actors involved. As the risk of the strong gas discourse leading to a discursive lock-in and subsequently to the prevention or deceleration of the heat transition has been pointed out, the urgent need to act has been demonstrated. Moreover, the risk of sunk investments that would lead to high transition costs in the future when it comes to compensation payments on the one hand, as well as creating carbon lock-ins that could hinder Germany from fulfilling its climate goals in the building sector are reasons for political concern. Yet, there is currently a window of opportunity that policymakers should make use of to introduce policy measures, as the acceptance within society is most likely higher. Thus, policymakers should use the moment to stimulate the heat transition and utilise the potentially higher willingness of building managers to change their heating system. Generally, policymakers should aim to reduce uncertainty in the heating sector of buildings by

developing clear strategies and guidelines for the heat transition. This is most crucial, having the contradictory discourses in mind that could lead to ambiguities for businesses and private customers alike in how to choose the heating solutions for their buildings. Policymakers should aim to establish the heating options that are, from a scientific point, environmentally preferrable and economically and politically feasible. They should eliminate any ambiguity linked to a lack of knowledge of heating customers, businesses, and further societal as well as political actors by a clear communication of facts. Based on the findings of this thesis, especially considering the negative climate consequences of natural gas, the risk of fossil fuel dependencies, and the suitability of alternative heating solutions, a fast and determined exit strategy from natural gas is recommended. It is also recommended to formulate a clear position concerning the use of hydrogen and other low-carbon gases in the heating sector. As their potential, costs, and climate impacts are uncertain at the moment, it is recommended to prioritise 'no-regret' measures, i.e., to support the expansion of alternative heating solutions, especially heat pumps and decarbonised heat networks. Clear communication that hydrogen might only be used in certain exceptions for the heating of buildings, but that the general pathway will be electrification, would reduce speculations and would prevent the gas discourse coalition to utilise the hydrogen utopia to defend the status of the gas industry.
As the likelihood of a discursive lock-in leading to a continuous stagnation of the heat transition has been demonstrated, it is recommended to introduce strict policy measures to break that discourse. Due to the predominant gas discourse that defends the role natural gas-based heating has at the moment, it will be challenging to roll out renewable heating options without clear policy incentives. In that sense, recommendations for administrative and regulative policy instruments include a ban on the instalment of natural gas-based heating as soon as possible. Concerning economic or market-based policy instruments, a priority should be to set the right price signals that would support the uptake of renewable heating solutions. This would include, e.g., strengthening the subsidies for low-carbon heating solutions, and increasing the price of natural gas by including the externalities in the price. For the latter point, the emission trading system is a step in the right direction, however, the price needs to rise to mirror the real costs. Lastly, communicative and informative policy instruments are crucial to increase the awareness of the need for the heat transition in society. With the help of communication campaigns, alternative discourses could be strengthened, by, e.g., boosting the positive image of renewable heating solutions. Furthermore, communication should be used to address some of the common misbelieves and misinformation that are to some extent also induced by the discourses, and should, for instance, demonstrate the suitability and advantages of the use of heat pumps across various building types, and highlight the need to phase out natural gas-based heating.

Second, some recommendations for *practitioners* can be made, for instance, for energy providers, gas network operators, and heating technology manufacturers. In general, those businesses should critically reflect upon the proposed pathway for the heat transition and examine dominant discourses based on available research. Accordingly, energy providers and gas network operators should prepare for a transition away from natural gas and should adapt their business models accordingly. It is recommended to be cautious about planning to switch their natural gas-based operations to hydrogen, as it is uncertain if, when, and at what costs hydrogen will be available. For the heating of buildings, other heating solutions will likely play a more important role, which should be considered in their business strategies. For heating technology manufacturers, a business opportunity in the uptake of the production of heat pumps is seen, and it is recommended to adapt their portfolio accordingly.
In addition, other practitioners that are working on advancing the heat transition can profit from the insights of this thesis. For instance, NGOs can align their campaigns to challenge the dominant gas discourse and address some of the common misconceptions induced by the gas discourse. Their communication should reduce the ambiguity that stems from the diverging discourses.

Lastly, *private heating customers* can benefit from the results of this thesis. For private customers, there is a particular risk that, if they have less knowledge on or are less familiar with technical topics like the heating system of their buildings, they will follow dominant discourses. In this case, for instance, as natural gas is portrayed as the standard heating solution that entails many benefits, heating customers might follow that proposed solution and not question their usage of natural gas. However, this thesis has emphasised the need to critically reflect upon dominant discourses. Heating customers should engage in efforts to find the best way for the heating of their buildings to contribute to the emission reduction goals in the building sector. In that sense, for instance, it is recommended, that private customers utilise consultancy services like the 'individual renovation roadmap (iSFP)' to develop strategies on how to transform their buildings in line with the decarbonisation needs of the heat transition.

8.3 Further Research

By adopting a constructivist approach to identify and analyse prominent narratives and the discourses they feed into, this thesis has made a valuable contribution to the literature on the German heat transition in the building sector. So far, energy transition research has mostly been focused on the electricity sector, and thus, there is less knowledge on the heat transition. Furthermore, while literature has pointed out the value of applying interpretative research in connection with transition research and studies on carbon lock-ins, the amount of research in that field is still limited. This thesis has demonstrated that analysing narratives and discourses helps to create a deeper understanding of energy transitions and understand the role of discourses in lock-in creation. A theoretical framework on discursive lock-ins has been adapted and expanded, which serves as a contribution to the theoretical work on the role of discourses and narratives in transition research. The framework illustrates the relationship between discourses and narratives as well as discourse coalitions within socio-technical systems. Furthermore, it shows how discursive lock-ins can emerge on different levels, which potentially can stabilise an existing socio-technical regime and prevent change. Discursive turning points are illustrated as windows of opportunity to accelerate a transition.

Some suggestions for further research can be made. First, research could address some of the limitations of this work, especially regarding the limited number of interviews and documents analysed. By including more data in the analysis, the validity of the findings would be strengthened. Furthermore, it would be interesting to compare studies from different geographical scopes to account for context-specific factors and understand, e.g., if Germany's large dependency on natural gas influences the discourses. A more nuanced actor analysis of the actors that are included in the discourse coalitions within this thesis, but also of further actors not considered within this thesis, would further add to the understanding of what strategies the actors pursue in their framings and argumentations. This would demonstrate the similarities and differences between the narratives and discourses employed by the actors that got lost by the grouping into discourse coalitions within this thesis.

Second, this thesis has indicated that hydrogen and other low-carbon gases are increasingly included in the discussion around gas in the heating of buildings. It has also been suggested that advocating for the inclusion of these alternative gases might be a strategy of regime actors of the gas industry to defend the role and status of their industry. This constitutes a promising research field: By an in-depth analysis of the narratives and discourses around alternative low-carbon gases, the strategies behind the advocators and the implications for the heat transition in the building sector could be revealed.

Lastly, further research is recommended that takes the implications of the Russian war on German's energy transition into account. While this thesis has suggested that the war constitutes a disruptive discursive change that might provide a window of opportunity to accelerate the

heat transition, further research in that area is needed. Potentially, studies could focus on changes in policies and in general in the political discourse that emerged as a reaction to the war. It would be interesting to see if certain policies, e.g., a phase-out of natural gas in the building sector, will be moved up in time. Furthermore, studies could investigate how the public perception of natural gas and the general awareness of the German heat transition in society changed as a reaction to the war. For instance, the effects on the sales of heat pumps or the switch of heating technology, in general, could be investigated, along with an analysis of the motivation behind that switch. Furthermore, a comparison of discourses over time would be insightful to see how the outbreak of the Russian war has changed the debate around natural gas in Germany's heat transition.

Bibliography

Adams, W. C. (2015). Conducting semi-structured interviews. In J. S. Wholey, H. P. Hatry, & K. E. Newcomer (Eds.), *Handbook of practical program evaluation* (Vol. 4, pp. 492–505). Wiley Hoboken, NJ, USA.

AEE (Agentur für Erneuerbare Energien e.V.) [Agency for Renewable Energies]. (2020). *Endenergieverbrauch nach Anwendungsbereichen [Final energy use by use area]*. https://www.unendlich-viel-energie.de/mediathek/grafiken/endenergieverbrauch-nach-anwendungsbereichen-2018

AEE (Agentur für Erneuerbare Energien e.V.) [Agency for Renewable Energies]. (2021a). *Beheizungsstrukture des Wohngebäudebestands 2019 [Heating structure of the housing stock in Germany 2019]*. https://www.unendlich-viel-energie.de/mediathek/grafiken/beheizungsstruktur-im-bestand-und-neubau

AEE (Agentur für Erneuerbare Energien e.V.) [Agency for Renewable Energies]. (2021b). *Endenergieverbrauch für Wärme und Kälte in Deutschland 2019 [Final energy consumption for heating and cooling in Germany 2019]*. https://www.unendlich-viel-energie.de/mediathek/grafiken/endenergieverbrauch-fuer-waerme-und-kaelte-in-deutschland-2019

AGEB (AG Energiebilanzen e.V.). (2021). *Anwendungsbilanzen zur Energiebilanz Deutschland. Endenergieverbrauch nach Energieträgern und Anwendungszwecken [Assessments of the energy use in Germany. Final energy consumption according to energy sources and application purposes]*. https://ag-energiebilanzen.de/wp-content/uploads/2020/10/ageb_20v_v1.pdf

Agora Energiewende (2021). *Worüber keiner reden will: Der bevorstehende Abschied vom Gasnetz [What no one wants to talk about: The imminent end of the gas grid]*. https://www.agora-energiewende.de/blog/worueber-keiner-reden-will-der-bevorstehende-abschied-vom-gasnetz/

Ahmels, P., Bosse, J., Brauers, H., Braunger, I., Gheorghiu, A., Häublein, E., Holz, F., Kemfert, C., & Präger, F. (2021). *Am Klimaschutz vorbeigeplant Klimawirkung, Bedarf und Infrastruktur von Erdgas in Deutschland: Hintergrundpapier [Planning past climate protection - Climate impact, demand, and infrastructure of natural gas in Germany: Background paper]*. https://www.diw.de/documents/publikationen/73/diw_01.c.815872.de/diwkompakt_2021-166.pdf

Alvarez, R. A., Pacala, S. W., Winebrake, J. J., Chameides, W. L., & Hamburg, S. P. (2012). Greater focus needed on methane leakage from natural gas infrastructure. *Proceedings of the National Academy of Sciences*, *109*(17), 6435–6440. https://doi.org/10.1073/pnas.1202407109

Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., Davis, K. J., Herndon, S. C., Jacob, D. J., Karion, A., Kort, E. A., Lamb, B. K., Lauvaux, T., Maasakkers, J. D., Marchese, A. J., Omara, M., Pacala, S. W., Peischl, J., Robinson, A. L., … Hamburg, S. P. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. *Science*, *361(6398),* 186–188. https://doi.org/10.1126/science.aar7204

Amelang, S., Appunn, K., & Wehrmann, B. (2022). *Ukraine war: Tracking the impacts on German energy and climate policy | Clean Energy Wire*. Clean Energy Wire. https://www.cleanenergywire.org/news/ukraine-war-tracking-impacts-german-energy-and-climate-policy

Ampe, K., Paredis, E., Asveld, L., Osseweijer, P., & Block, T. (2020). A transition in the Dutch wastewater system? The struggle between discourses and with lock-ins. *Journal of Environmental Policy & Planning*, *22*(2), 155–169. https://doi.org/10.1080/1523908X.2019.1680275

Andrews-Speed, P. (2016). Applying institutional theory to the low-carbon energy transition. *Energy Research & Social Science*, *13*, 216–225. https://doi.org/10.1016/j.erss.2015.12.011

Baldino, C., O'Malley, J., Searle, S., & Christensen, A. (2021). *Hydrogen for heating? Decarbonization options for households in Germany in 2050*. https://www.euagenda.com/upload/publications/hydrogen-heating-germany-en-apr2021.pdf

Ballo, I. F. (2015). Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway. *Energy Research & Social Science*, *9*, 9–20. https://doi.org/10.1016/j.erss.2015.08.015

Baudisch, K., & Fouquet, D. (2019). Germany's coal exit plan–a legal and political outline on how Germany plans to phase out coal fired power stations by 2038. *Renewable Energy Law and Policy Review*, *9*(2), 45–59. https://www.jstor.org/stable/26743439

BBC. (2022). Nord Stream 2: How does the pipeline fit into Ukraine-Russia crisis? *BBC Web*. https://www.bbc.com/news/world-europe-60131520

BDEW (Bundesverband der Energie- und Wasserwirtschaf) [federal association of the energy and water industries]. (n.d.-a). *Die Rolle von Erdgas in der Energiewende [The role of natural gas in the energy transition]*. https://www.bdew.de/energie/erdgas/die-rolle-von-erdgas-der-energiewende/

BDEW (Bundesverband der Energie- und Wasserwirtschaf) [federal association of the energy and water industries]. (n.d.-b). *Wärmewende mit Gas [Heat transition with gas]*. https://www.bdew.de/energie/erdgas/waermewende-mit-gas/

BDEW (Bundesverband der Energie- und Wasserwirtschaf) [federal association of the energy and water industries]. (2020). *Beheizungsstruktur des Wohnungsbestandes in Deutschland 2020 [Heating structure of the housing stock in Germany]*. https://www.bdew.de/service/daten-und-grafiken/beheizungsstruktur-wohnungsbestand-deutschland/

BEE (Bundesverband Erneuerbare Energie) [federal association of renewable energies]. (2021). *Legislatur der Wärme – Was jetzt zu tun ist [Legislature of heat – What needs to be done now]*. https://www.bee-ev.de/fileadmin/Publikationen/Positionspapiere_Stellungnahmen/20211119_BEE_Legislatur_der_W%C3%A4rme.pdf

Bekkering, J., Broekhuis, A. A., van Gemert, W. J. T., & Hengeveld, E. J. (2013). Balancing gas supply and demand with a sustainable gas supply chain – A study based on field data. *Applied Energy*, *111*, 842–852. https://doi.org/10.1016/j.apenergy.2013.05.073

Berglund, M., & Börjesson, P. (2006). Assessment of energy performance in the life-cycle of biogas production. *Biomass and Bioenergy*, *30*(3), 254–266. https://doi.org/10.1016/j.biombioe.2005.11.011

Bernath, C., Deac, G., & Sensfuß, F. (2019). Influence of heat pumps on renewable electricity integration: Germany in a European context. *Energy Strategy Reviews*, *26*, 100389. https://doi.org/10.1016/j.esr.2019.100389

Bessi, A., Guidolin, M., & Manfredi, P. (2021). The role of gas on future perspectives of renewable energy diffusion: Bridging technology or lock-in? *Renewable and Sustainable Energy Reviews*, *152*, 111673. https://doi.org/10.1016/j.rser.2021.111673

Blesl, M., Koziol, M., Ludwig, M. C., Rapp, H., Tenberg, B., Vautz, S., & Wolf, S. (2018). 40/40-Strategie: Unser Konzept für die Wärmewende [40/40 Strategy: Our concept for the heat transition]. *AGFW (Der Energieeffizienzverband Für Wärme, Kälte Und KWK)*. https://www.agfw.de/strategien-der-waermewende/perspektive-der-fw-7070-4040/#:~:text=Die%2040%2F40%2DStrategie%20f%C3%B6rdert,Mittelst%C3%A4dten%20und%20dem%20l%C3%A4ndlichen%20Raum.

BMF (Bundesministerium der Finanzen) [Ministry of Finances]. (2022). *Maßnahmenpaket des Bundes zum Umgang mit den hohen Energiekosten [Federal package of measures to deal with high energy costs]*. https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Schlaglichter/Entlastungen/massnahmenpaket-bund-hohe-energiekosten.html

BMU (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit) [Federal Ministry for the Environment Nature Conservation, and Nuclear Safety]. (2021). *Klimaschutz in Zahlen: Fakten, Trends und Impulse deutscher Klimapolitik Ausgabe 2021 [Climate protection in figures: Facts, trends, and impulses of German climate policy edition 2021]*. https://www.bmuv.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutz_zahlen_2021_bf.pdf

BMWi (Bundesministerium für Wirtschaft und Energie) [Federal Ministry for Economic Affairs and Energy]. (2019). *Energieeffizienzstrategie 2050 [Energy efficiency strategy 2050]*. https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/energieeffiezienzstrategie-2050.pdf

BMWi (Bundesministerium für Wirtschaft und Energie) [Federal Ministry for Economic Affairs and Energy]. (2021). *Erdgasversorgung in Deutschland [Natural gas supply in Germany]*. https://www.bmwi.de/Redaktion/DE/Artikel/Energie/gas-erdgasversorgung-in-deutschland.html

BMWK (Bundesministerium für Wirtschaft und Klimaschutz) [Federal Ministry for Economic Affairs and Climate Action]. (2021). *Treibhausgasemissionen in Deutschland nach Sektoren [Greenhouse gas emissions in Germany by sector]*. https://www.bmwi.de/Redaktion/DE/Infografiken/Industrie/treibhausgasemissionen-deutschland-nach-sektoren.html

BMWK (Bundesministerium für Wirtschaft und Klimaschutz) [Federal Ministry for Economic Affairs and Climate Action]. (2022). *Effiziente Gebäude [Efficient buildings]*. https://www.bmwi.de/Redaktion/DE/Dossier/energiewende-im-gebaeudebereich.html

Bockelmann, F., & Fisch, M. N. (2019). It Works—Long-Term Performance Measurement and Optimization of Six Ground Source Heat Pump Systems in Germany. *Energies*, *12*(24), 4691. https://doi.org/10.3390/en12244691

Börjesson, M., & Ahlgren, E. O. (2012). Cost-effective biogas utilisation – A modelling assessment of gas infrastructural options in a regional energy system. *Energy*, *48*(1), 212–226. https://doi.org/10.1016/j.energy.2012.06.058

Bosman, R., Loorbach, D., Frantzeskaki, N., & Pistorius, T. (2014). Discursive regime dynamics in the Dutch energy transition. *Environmental Innovation and Societal Transitions*, *13*, 45–59. https://doi.org/10.1016/j.eist.2014.07.003

Brauers, H., Braunger, I., Hoffart, F., Kemfert, C., Oei, P.-Y., Präger, F., Schmalz, S., & Troschke, M. (2021). *Ausbau der Erdgas-Infrastruktur: Brückentechnologie oder Risiko für die Energiewende? [Expansion of the natural gas infrastructure: Bridge technology or risk for the energy transition?]* https://doi.org/10.5281/ZENODO.4474498

Brauers, H., Braunger, I., & Jewell, J. (2021). Liquefied natural gas expansion plans in Germany: The risk of gas lock-in under energy transitions. *Energy Research & Social Science*, *76*, 102059. https://doi.org/10.1016/j.erss.2021.102059

Braun, V., & Clarke, V. (2021). One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology*, *18*(3), 328–352. https://doi.org/10.1080/14780887.2020.1769238

Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019). Thematic Analysis. In P. Liamputtong (Ed.), *Handbook of Research Methods in Health Social Sciences* (pp. 843–860). Springer Singapore. https://doi.org/10.1007/978-981-10-5251-4_103

Bryman, A. (2012). *Social research methods* (4th ed). Oxford University Press.

Bulkeley, H. (2000). Discourse Coalitions and the Australian Climate Change Policy Network. *Environment and Planning C: Government and Policy*, *18*(6), 727–748. https://doi.org/10.1068/c9905j

Bundes-Klimaschutzgesetz [National Climate Change Act], (2021). https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/ksg_aendg_2021_bf.pdf

Bundesnetzagentur. (2021). *Monitoringbericht 2021 [Monitoring report 2021]*. https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Monitoringberichte/Monitoringbericht_Energie2021.pdf?__blob=publicationFile&v=2

Buschmann, P., & Oels, A. (2019). The overlooked role of discourse in breaking carbon lock-in: The case of the German energy transition. *WIREs Climate Change*, *10*(3). https://doi.org/10.1002/wcc.574

BVEG (Bundesverband Erdgas, Erdöl und Geoenergie) [federal association of natural gas, oil, and geo-energy Germany]. (2022). *Wie Erdgas zum Klimaschutz beiträgt [How natural gas contributes to climate protection]*. https://www.bveg.de/die-branche/beitrag-zum-klimaschutz/wie-erdgas-zum-klimaschutz-beitraegt/

BWP (Bundesverband Wärmepumpe) [federal association heat pumps]. (2021). *Roadmap Wärmepumpe. Der Weg zur Dekarbonisierung des Gebäudesektors [Roadmap heat pump. The pathway to decarbonise the building sector]*. https://www.waermepumpe.de/fileadmin/user_upload/waermepumpe/07_Publikationen/Sonstige/2021-04-29_BWP_Roadmap_final.pdf

BWP (Bundesverband Wärmepumpe) [federal association heat pumps]. (2022). *Absatzzahlen [Sales figures]*. https://www.waermepumpe.de/presse/zahlen-daten/absatzzahlen/

Byrne, D. (2021). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality & Quantity*. https://doi.org/10.1007/s11135-021-01182-y

Byrne, R., Smith, A., Watson, J., & Ockwell, D. (2012). Energy pathways in low carbon development. In D. Ockwell & A. Mallet (Eds.), *Low-Carbon Technology Transfer: From Rhetoric to Reality*. Routledge, London & New York.

Cherp, A., Vinichenko, V., Jewell, J., Brutschin, E., & Sovacool, B. (2018). Integrating techno-economic, socio-technical and political perspectives on national energy transitions: A meta-theoretical framework. *Energy Research & Social Science*, *37*, 175–190. https://doi.org/10.1016/j.erss.2017.09.015

co2online. (n.d.-a). *Brennstoffe & Energieträger: Wichtige Fragen und direkter Vergleich [Fuels & energy sources: Important questions and direct comparison]*. https://www.co2online.de/modernisieren-und-bauen/heizung/brennstoffe-energietraeger-im-vergleich/#c94177

co2online. (n.d.-b). *Energiewende in Deutschland: Definition, Kosten & Ziele [Energy transition in Germany: Definition, costs & goals]*. https://www.co2online.de/klima-schuetzen/energiewende/energiewende-definition-ziele-uebersicht/#c150159

co2online: Wohnen und Sanieren. (n.d.). *Gebäude. Baualtersklassen [Buildings, Construction age categories]*. https://www.wohngebaeude.info/daten/#/gebaeude/bundesweit;main=gebaeudealter

Collet, P., Flottes, E., Favre, A., Raynal, L., Pierre, H., Capela, S., & Peregrina, C. (2017). Techno-economic and Life Cycle Assessment of methane production via biogas upgrading and power to gas technology. *Applied Energy*, *192*, 282–295. https://doi.org/10.1016/j.apenergy.2016.08.181

Cotton, M., Rattle, I., & Van Alstine, J. (2014). Shale gas policy in the United Kingdom: An argumentative discourse analysis. *Energy Policy*, *73*, 427–438. https://doi.org/10.1016/j.enpol.2014.05.031

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Delborne, J. A., Hasala, D., Wigner, A., & Kinchy, A. (2020). Dueling metaphors, fueling futures: "Bridge fuel" visions of coal and natural gas in the United States. *Energy Research & Social Science*, *61*, 101350. https://doi.org/10.1016/j.erss.2019.101350

dena (Deutsche Energie-Agentur) [German energy agency]. (2018). *Dena-Leitstudie. Integrierte Energiewende. Impulse für die Gestaltung des Energiesystems bis 2050 [dena lead study. Integrated energy transition. Impulses for shaping the energy system until 2050]*. https://www.dena.de/fileadmin/dena/Dokumente/Pdf/9261_dena-Leitstudie_Integrierte_Energiewende_lang.pdf

dena (Deutsche Energie-Agentur) [German energy agency]. (2021a). *dena-Gebäudereport 2022. Zahlen, Daten, Fakten [dena building report. Numbers, dates, facts]*. https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2021/dena-Gebaeudereport_2022.pdf

dena (Deutsche Energie-Agentur) [German energy agency]. (2021b). *dena-Leitstudie Aufbruch Klimaneutralität [dena lead study. The road to climate neutrality]*. https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2021/Abschlussbericht_dena-Leitstudie_Aufbruch_Klimaneutralitaet.pdf

Deutscher Bundestag. (2020). *Bundestag erhöht Zertifikatspreise im Emissionshandel [Bundestag increases certificate prices in emissions trading]*. https://www.bundestag.de/dokumente/textarchiv/2020/kw41-de-brennstoffemissionshandelsgesetz-795992

Die Bundesregierung. (2022a). *Bausteine der Energiewende. Einfacher Wärme sparen in Gebäuden. Gebäudeenergiegesetz [Building blocks of the energy transition. Saving heat in buildings more easily. Building Energy Act]*. https://www.bundesregierung.de/breg-de/themen/klimaschutz/gebaeudeenergiegesetz-1684496

Die Bundesregierung. (2022b). *Klimaschutz. Bauen und Wohnen [Climate protection. Construction and living]*. https://www.bundesregierung.de/breg-de/themen/klimaschutz/klimafreundliches-zuhause-1792146

DIW (Deutsches Institut für Wirtschaftsforschung) [German institute for economic research] & DUH (Deutsche Umwelthilfe). (2021). *Am Klimaschutz vorbeigeplant Klimawirkung, Bedarf und Infrastruktur von Erdgas in Deutschland: Hintergrundpapier [Planning past climate protection - Climate impact, demand, and infrastructure of natural gas in Germany: Background paper]*. https://www.diw.de/documents/publikationen/73/diw_01.c.815872.de/diwkompakt_2021-166.pdf

Dunkelberg, E., Weiß, J., & Hirschl, B. (2020). *Wärmewende in Städten gestalten. Empfehlungen für eine sozial-ökologische Transformation der Wärmeversorgung in Berlin [Shaping the heat transition in cities. Recommendations for a social-ecological transformation of the heat supply in Berlin]*. IÖW. https://www.nachhaltige-zukunftsstadt.de/downloads/Dunkelberg_et_al_2020_Waermewende_in_Staedten_gestalten.pdf

Economides, M. J., & Wood, D. A. (2009). The state of natural gas. *Journal of Natural Gas Science and Engineering*, *1*(1–2), 1–13. https://doi.org/10.1016/j.jngse.2009.03.005

Energy Systems Catapult. (2022). *All housing types are suitable for heat pumps, finds Electrification of Heat project*. https://es.catapult.org.uk/news/electrification-of-heat-trial-finds-heat-pumps-suitable-for-all-housing-types/

Engelmann, P., Köhler, B., Meyer, R., Dengler, J., Herkel, S., Kießling, L., Quast, A., Berneiser, J., Bär, C., Sterchele, P., Heilig, J., Bürger, V., Köhler, B., Braungardt, S., Hesse, T., Sandrock, M., Maaß, C., & Strodel, N. (2021). *Systemische Herausforderung der Wärmewende. Abschlussbericht [Systemic challenge of the heat transition. Final report]* (No. 18/2021; Climate Change). Umweltbundesamt (UBA). https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-04-26_cc_18-2021_waermewende.pdf

E.ON. (2020). *Energiewende mit grünem Gas kommt einkommensschwachen Haushalten zugute [Energy transition with green gas benefits low-income households]*. https://www.eon.com/de/ueber-uns/politischer-dialog/energiewende-mit-gruenem-gas.html

Erickson, P., Kartha, S., Lazarus, M., & Tempest, K. (2015). Assessing carbon lock-in. *Environmental Research Letters*, *10*(8), 084023. https://doi.org/10.1088/1748-9326/10/8/084023

European Commission. (n.d.-a). *A European Green Deal*. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#documents

European Commission. (n.d.-b). *Energy performance of buildings directive*. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

Faramawy, S., Zaki, T., & Sakr, A. A.-E. (2016). Natural gas origin, composition, and processing: A review. *Journal of Natural Gas Science and Engineering*, *34*, 34–54. https://doi.org/10.1016/j.jngse.2016.06.030

Fisch-Romito, V., Guivarch, C., Creutzig, F., Minx, J. C., & Callaghan, M. W. (2021). Systematic map of the literature on carbon lock-in induced by long-lived capital. *Environmental Research Letters*, *16*(5), 053004. https://doi.org/10.1088/1748-9326/aba660

Fitzgerald, L. M., Braunger, I., & Brauers, H. (2019). *Destabilisation of Sustainable Energy Transformations: Analysing Natural Gas Lock-in in the case of Germany* (STEPS Working Paper 106). https://opendocs.ids.ac.uk/opendocs/bitstream/handle/20.500.12413/14499/WP_106_Fitzgerald_et._al.%20FINAL_Jan_2020.pdf?sequence=108&isAllowed=y

FNB Gas (Vereinigung der Fernleitungsnetzbetreiber Gas e.V.) [association of supra-regional gas transmission operators]. (2021). *The value of hydrogen in the heating market. An analysis of different heating technologies with a focus on hydrogen condensing boilers and electric heat pumps. Study for FNB Gas*. frontier economics. https://fnb-gas.de/wp-content/uploads/2021/09/frontier_-_fnb_gas_-_h2_in_heating_market.pdf

FNB Gas (Vereinigung der Fernleitungsnetzbetreiber Gas e.V.) [association of supra-regional gas transmission operators]. (2022a). *Erdgas ist die Nummer eins im Heizungskeller [Natural gas is the number one heating option]*. https://gas.info/energie-gas/erdgas/verwendung-erdgas/heizung

FNB Gas (Vereinigung der Fernleitungsnetzbetreiber Gas e.V.) [association of supra-regional gas transmission operators]. (2022b). *LNG-Terminals in Deutschland [LNG terminals in Germany]*. https://gas.info/mobil-verkehr/lng/lng-import-herkunft/lng-terminal

FOES (Forum Forum Ökologisch-Soziale Marktwirtschaft) (Ed.). (2021). *Was Erdgas wirklich kostet: Roadmap für den fossilen Gasausstieg im Wärmesektor [What natural gas really costs: Roadmap for the fossil gas phase-out in the heating sector]. Studie 06/2021*. https://foes.de/publikationen/2021/2021-06_FOES_Roadmap_Gasausstieg.pdf

Frank, L., Jacob, K., & Quitzow, R. (2020). Transforming or tinkering at the margins? Assessing policy strategies for heating decarbonisation in Germany and the United Kingdom. *Energy Research & Social Science*, *67*, 101513. https://doi.org/10.1016/j.erss.2020.101513

Fraunhofer IWES/IBP. (2017). Wärmewende 2030. Schlüsseltechnologien zur Erreichung der mittel-und langfristigen Klimaschutzziele im Gebäudesektor [Heat transition 2030. Key technologies for achieving the medium and long-term climate protection targets in the building sector]. *Agora, Berlin*, 96. https://www.agora-energiewende.de/fileadmin/Projekte/2016/Sektoruebergreifende_EW/Waermewende-2030_WEB.pdf

García-Horta, J. B., & Guerra-Ramos, M. T. (2009). The use of CAQDAS in educational research: Some advantages, limitations and potential risks. *International Journal of Research & Method in Education*, *32*(2), 151–165. https://doi.org/10.1080/17437270902946686

Gaur, A. S., Fitiwi, D. Z., & Curtis, J. A. (2019). *Heat pumps and their role in decarbonising heating sector: A comprehensive review*. https://www.econstor.eu/handle/10419/228269

Gawel, E., Lehmann, P., Korte, K., Strunz, S., Bovet, J., Köck, W., Massier, P., Löschel, A., Schober, D., Ohlhorst, D., Tews, K., Schreurs, M., Reeg, M., & Wassermann, S. (2014). The future of the energy transition in Germany. *Energy, Sustainability and Society*, *4*(1), 15. https://doi.org/10.1186/s13705-014-0015-7

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, *36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Geels, F. W., & Verhees, B. (2011). Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986). *Technological Forecasting and Social Change*, *78*(6), 910–930. https://doi.org/10.1016/j.techfore.2010.12.004

Giehl, J., Sudhaus, T., Kurre, A., Mikulicz-Radecki, F. v., Hollnagel, J., Wacker, M., Himmel, J., & Müller-Kichenbauer, J. (2021). Modelling the impact of the energy transition on gas distribution networks in Germany. *Energy Strategy Reviews*, *38*, 100751. https://doi.org/10.1016/j.esr.2021.100751

Gilbert, A. Q., & Sovacool, B. K. (2017). Benchmarking natural gas and coal-fired electricity generation in the United States. *Energy*, *134*, 622–628. https://doi.org/10.1016/j.energy.2017.05.194

Greenpeace. (2021). *Factsheet: Fossiles Gas [Factsheet: Natural gas]*. https://www.greenpeace.de/klimaschutz/energiewende/gasausstieg

Gründinger, W. (2015). *What drives the Energiewende?* [Doctoral dissertation, Humboldt University Berlin]. https://www.researchgate.net/profile/Wolfgang-Gruendinger/publication/315363778_The_Energy_Transformation_in_Germany/links/5ff31fa592851c13feeb0bd5/The-Energy-Transformation-in-Germany.pdf

Gürsan, C., & de Gooyert, V. (2021). The systemic impact of a transition fuel: Does natural gas help or hinder the energy transition? *Renewable and Sustainable Energy Reviews*, *138*, 110552. https://doi.org/10.1016/j.rser.2020.110552

Hainsch, K., Göke, L., Kemfert, C., Oei, P.-Y., & von Hirschhausen, C. R. (2020). European Green Deal: Mit ambitionierten Klimaschutzzielen und erneuerbaren Energien aus der Wirtschaftskrise [European Green Deal: Out of the economic crisis with ambitious climate protection targets and renewable energies]. *DIW Wochenbericht*, *87*(28), 499–506. https://www.diw.de/de/diw_01.c.793327.de/publikationen/wochenberichte/2020_28_1/european_green_deal__mit_ambitionierten_klimaschutzzielen_und_erneuerbaren_energien_aus_der_wirtschaftskrise.html

Hajer, M. (1993). Discourse coalitions. In F. Fischer & J. Forester (Eds.), *The Argumentative Turn in Policy Analysis and Planning*. Duke University Press.

Hajer, M. A. (1995). *The politics of environmental discourse: Ecological modernization and the policy process*. Clarendon Press.

Hamelin, L., Naroznova, I., & Wenzel, H. (2014). Environmental consequences of different carbon alternatives for increased manure-based biogas. *Applied Energy*, *114*, 774–782. https://doi.org/10.1016/j.apenergy.2013.09.033

Hausfather, Z. (2015). Bounding the climate viability of natural gas as a bridge fuel to displace coal. *Energy Policy*, *86*, 286–294. https://doi.org/10.1016/j.enpol.2015.07.012

Henger, R., Runst, P., & Voigtländer, M. (2017). *Energiewende im Gebäudesektor. Handlungsempfehlungen für mehr Investitionen in den Klimaschutz [Energy transition in the building sector. Recommendations for more investment in climate protection]*. Institut der deustchen Wirtschaft Köln. https://www.iwkoeln.de/studien/ralph-henger-michael-voigtlaender-handlungsempfehlungen-fuer-mehr-investitionen-in-den-klimaschutz.html

Heracleous, L., & Fernandes, O. (2019). *Challenges in Coding Qualitative Data*. SAGE Publications Ltd. https://doi.org/10.4135/9781526476210

Hermwille, L. (2016). The role of narratives in socio-technical transitions—Fukushima and the energy regimes of Japan, Germany, and the United Kingdom. *Energy Research & Social Science*, *11*, 237–246. https://doi.org/10.1016/j.erss.2015.11.001

Hertle, H., Pehnt, M., Gugel, B., Dingeldey, M., & Müller, K. (2015). *Wärmewende in Kommunen: Leitfaden für den klimafreundlichen Umbau der Wärmeversorgung [Heat transition in municipalities: Guidelines for the climate-friendly conversion of*

the heat supply system] (3. Aufl). Heinrich-Böll-Stiftung. https://www.boell.de/de/2015/09/30/waermewende-kommunen

Hilpert, S. (2020). Effects of Decentral Heat Pump Operation on Electricity Storage Requirements in Germany. *Energies*, *13*(11), 2878. https://doi.org/10.3390/en13112878

Horton, J., Macve, R., & Struyven, G. (2004). Qualitative Research: Experiences in Using Semi-Structured Interviews. In C. Humphrey & B. Lee (Eds.), *The Real Life Guide to Accounting Research* (pp. 339–357). Elsevier. https://doi.org/10.1016/B978-008043972-3/50022-0

Howarth, R. W. (2014). A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas. *Energy Science & Engineering*, *2*(2), 47–60. https://doi.org/10.1002/ese3.35

Huchtemann, K., & Müller, D. (2012). Evaluation of a field test with retrofit heat pumps. *Building and Environment*, *53*, 100–106. https://doi.org/10.1016/j.buildenv.2012.01.013

IEA (International Energy Agency). (2021). *Net Zero by 2050*. https://www.iea.org/reports/net-zero-by-2050

IEA (International Energy Agency). (2022). *Russia's War on Ukraine*. https://www.iea.org/topics/russia-s-war-on-ukraine#key-points

International Council on Clean Transportation. (2019). *Gas definitions for the European Union—International Council on Clean Transportation*. https://theicct.org/publication/gas-definitions-for-the-european-union/

IPCC (International Panel on Climate Change). (2022). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. doi: 10.1017/9781009157926

Jahn, D., & Korolczuk, S. (2012). German exceptionalism: The end of nuclear energy in Germany! *Environmental Politics*, *21*(1), 159–164. doi: 10.1080/09644016.2011.643374

Jenkins-Smith, H. C., Nohrstedt, D., Weible, C. M., & Sabatier, P. A. (2014). The advocacy coalition framework: Foundations, evolution, and ongoing research. In C.M. Weible & P.A. Sabatier (Eds.), *Theories of the policy process* (Vol. 3, pp. 183–224). Westview Press Boulder, CO.

Jensen, I. G., Münster, M., & Pisinger, D. (2017). Optimizing the supply chain of biomass and biogas for a single plant considering mass and energy losses. *European Journal of Operational Research*, *262*(2), 744–758. https://doi.org/10.1016/j.ejor.2017.03.071

Jensen, I. G., Wiese, F., Bramstoft, R., & Münster, M. (2020). Potential role of renewable gas in the transition of electricity and district heating systems. *Energy Strategy Reviews*, *27*, 100446. https://doi.org/10.1016/j.esr.2019.100446

Joas, F., Pahle, M., Flachsland, C., & Joas, A. (2016). Which goals are driving the Energiewende? Making sense of the German Energy Transformation. *Energy Policy*, *95*, 42–51. https://doi.org/10.1016/j.enpol.2016.04.003

Kaufmann, M., & Wiering, M. (2022). The role of discourses in understanding institutional stability and change – an analysis of Dutch flood risk governance. *Journal of Environmental Policy & Planning*, *24*(1), 1–20. https://doi.org/10.1080/1523908X.2021.1935222

Keppler, J. H. (2012). The economic costs of the nuclear phase-out in Germany. *NEA News*, *30*(1), 8. https://www.oecd-nea.org/jcms/pl_14820

Kern, F. (2011). Ideas, Institutions, and Interests: Explaining Policy Divergence in Fostering 'System Innovations' towards Sustainability. *Environment and Planning C: Government and Policy*, *29*(6), 1116–1134. https://doi.org/10.1068/c1142

Kittel, M., Goeke, L., Kemfert, C., Oei, P.-Y., & von Hirschhausen, C. (2020). Scenarios for coal-exit in Germany—A model-based analysis and implications in the European context. *Energies*, *13*(8), 2041. doi: 10.3390/en13082041

Knopf, B., Kondziella, H., Pahle, M., Götz, M., Bruckner, T., & Edenhofer, O. (2011). Der Einstieg in den Ausstieg: Energiepolitische Szenarien für einen Atomausstieg in Deutschland [The start of the phase-out: Energy policy scenarios for a nuclear phase-out in Germany]. *Studie des Potsdamer Instituts für Klimafolgenforschung und des Instituts für Infrastruktur und Ressourcenmanagement der Universität Leipzig im Auftrag der Friedrich-Ebert-Stiftung, Potsdam, Leipzig*. https://library.fes.de/pdf-files/wiso/08340.pdf

Koalitionsvertrag 2021-2025 [Coalition agreement 2021-2025]. (2021). *Mehr Fortschritt wagen: Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit. Koalitionsvertrag zwischen SPD, Bündnis 90/Die Grünen und FDP [Daring more progress: Coalition for freedom, justice and sustainability. Coalition agreement between SPD, Bündnis90/Die Grünen and FDP]*. https://www.bundesregierung.de/breg-de/service/gesetzesvorhaben/koalitionsvertrag-2021-1990800

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*, 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Kusch, W., Schmidla, T., & Stadler, I. (2012). Consequences for district heating and natural gas grids when aiming towards 100% electricity supply with renewables. *Energy*, *48*(1), 153–159. https://doi.org/10.1016/j.energy.2012.06.054

Lainson, K., Braun, V., & Clarke, V. (2019). Being both narrative practitioner and academic researcher: A reflection on what thematic analysis has to offer narratively informed research. *International Journal of Narrative Therapy & Community Work*, *4*, 86–98. https://uwe-repository.worktribe.com/output/4820836

Leach, M., Scoones, I., & Stirling, A. (2010). Governing epidemics in an age of complexity: Narratives, politics and pathways to sustainability. *Global Environmental Change*, *20*(3), 369–377. https://doi.org/10.1016/j.gloenvcha.2009.11.008

Leipold, S., Feindt, P. H., Winkel, G., & Keller, R. (2019). Discourse analysis of environmental policy revisited: Traditions, trends, perspectives. *Journal of Environmental Policy & Planning*, *21*(5), 445–463. https://doi.org/10.1080/1523908X.2019.1660462

Leipold, S., & Winkel, G. (2016). Divide and conquer—Discursive agency in the politics of illegal logging in the United States. *Global Environmental Change*, *36*, 35–45. https://doi.org/10.1016/j.gloenvcha.2015.11.006

Leipold, S., & Winkel, G. (2017). Discursive Agency: (Re-)Conceptualizing Actors and Practices in the Analysis of Discursive Policymaking. *Policy Studies Journal*, *45*(3), 510–534. https://doi.org/10.1111/psj.12172

Leipprand, A., Flachsland, C., & Pahle, M. (2017). Advocates or cartographers? Scientific advisors and the narratives of German energy transition. *Energy Policy*, *102*, 222–236. https://doi.org/10.1016/j.enpol.2016.12.021

Libertson, F. (2021). Competing socio-technical narratives in times of grid capacity challenges: The representative case of Sweden. *Energy, Sustainability and Society*, *11*(1), 4. https://doi.org/10.1186/s13705-021-00279-4

Lowes, R., & Woodman, B. (2020). Disruptive and uncertain: Policy makers' perceptions on UK heat decarbonisation. *Energy Policy*, *142*, 111494. https://doi.org/10.1016/j.enpol.2020.111494

Lowes, R., Woodman, B., & Speirs, J. (2020). Heating in Great Britain: An incumbent discourse coalition resists an electrifying future. *Environmental Innovation and Societal Transitions*, *37*, 1–17. https://doi.org/10.1016/j.eist.2020.07.007

Maatsch, H. (2013). Die Re-Regulierung des Elektrizitätsmarktes in Deutschland. *Akteure Und Interessen in Der Debatte Um Kapazitätsmechanismen (Master Thesis). Freie Universität Berlin, Berlin*.

Mackieson, P., Shlonsky, A., & Connolly, M. (2019). Increasing rigor and reducing bias in qualitative research: A document analysis of parliamentary debates using applied thematic analysis. *Qualitative Social Work*, *18*(6), 965–980. https://doi.org/10.1177/1473325018786996

Maier, M. (2019). *Die neue Gaswelt. Studie—Perspektiven für eine effiziente und grüne Gasversorgung [The new gas world. Study—Prospects for an efficient and green gas supply]*. Agentur für Erneuerbare Energien e.V. https://www.gruene-bundestag.de/fileadmin/media/gruenebundestag_de/themen_az/energie/gruene-metastudie-gas-nov-2019.pdf

McBeth, M. K., Shanahan, E. A., & Jones, M. D. (2014). Introducing the narrative policy framework. In M. D. Jones, E. A. Shanahan, M. K. McBeth (Eds.), *The science of stories* (pp. 1–25). Springer.

McComas, K., & Shanahan, J. (1999). Telling Stories About Global Climate Change: Measuring the Impact of Narratives on Issue Cycles. *Communication Research*, *26*(1), 30–57. https://doi.org/10.1177/009365099026001003

Meibom, P., & Karlsson, K. (2010). Role of hydrogen in future North European power system in 2060. *International Journal of Hydrogen Energy*, *35*(5), 1853–1863. https://doi.org/10.1016/j.ijhydene.2009.12.161

Mellwig, P., Pehnt, D. M., & Lempik, J. (2021). *Energieeffizienz als Türöffner für erneuerbare Energien im Gebäudebereich [Energy efficiency as a door opener for renewable energies in the building sector]*. https://www.ifeu.de/fileadmin/uploads/landwirtschaft/pdf/_ifeu_2021__Energieeffizienz_als_T%C3%BCr%C3%B6ffner_f%C3%BCr_erneuerbare_Energien_im_Geb%C3%A4udebereich_Endbericht.pdf

Merkel, E., McKenna, R., Fehrenbach, D., & Fichtner, W. (2017). A model-based assessment of climate and energy targets for the German residential heat system. *Journal of Cleaner Production*, *142*, 3151–3173. https://doi.org/10.1016/j.jclepro.2016.10.153

Miara, M., Günther, D., Langner, R., Helmling, S., & Wapler, J. (2017). 10 years of heat pumps monitoring in Germany. Outcomes of several monitoring campaigns. From low-energy houses to un-retrofitted single-family dwellings. *12th IEA Heat Pump Conference*. http://hpc2017.org/wp-content/uploads/2017/05/K.1.5.1-10-years-of-heat-pumps-monitoring-in-Germany.pdf

Middleton, R. S., & Yaw, S. (2018). The cost of getting CCS wrong: Uncertainty, infrastructure design, and stranded CO2. *International Journal of Greenhouse Gas Control*, *70*, 1–11. https://doi.org/10.1016/j.ijggc.2017.12.011

Mohan, A., & Topp, K. (2018). India's energy future: Contested narratives of change. *Energy Research & Social Science*, *44*, 75–82. https://doi.org/10.1016/j.erss.2018.04.040

Munoz, L. A. H., Huijben, J. C. C. M., Verhees, B., & Verbong, G. P. J. (2014). The power of grid parity: A discursive approach. *Technological Forecasting and Social Change*, *87*, 179–190. https://doi.org/10.1016/j.techfore.2013.12.012

Nancy Carter, R. N., Bryant-Lukosius, D., & Alba DiCenso, R. N. (2014). The use of triangulation in qualitative research. *Oncology Nursing Forum*, *41*(5), 545. doi: 10.1188/14.ONF.545-547

Nasr, J., & Marsh, S. (2022). Analysis: In Ukraine crisis, Germany faces tough decisions over gas pipeline. *Reuters*. https://www.reuters.com/world/europe/ukraine-crisis-germany-faces-tough-decisions-over-gas-pipeline-2022-01-20/

Noga, J., & Wolbring, G. (2014). The Oil and Gas Discourse from the Perspective of the Canadian and Albertan Governments, Non-Governmental Organizations and the Oil and Gas Industry. *Energies*, *7*(1), 314–333. https://doi.org/10.3390/en7010314

Ocelík, P., & Osička, J. (2014). The framing of unconventional natural gas resources in the foreign energy policy discourse of the Russian Federation. *Energy Policy*, *72*, 97–109. https://doi.org/10.1016/j.enpol.2014.04.006

Oei, P.-Y., Hainsch, K., Löffler, K., von Hirschhausen, C. R., Holz, F., & Kemfert, C. (2019). Neues Klima für Europa: Klimaschutzziele für 2030 sollten angehoben werden [New Climate for Europe: Climate protection targets for 2030 should be raised]. *DIW Wochenbericht*, *86*(41), 753–760. https://www.diw.de/de/diw_01.c.682902.de/publikationen/wochenberichte/2019_41_1/neues_klima_fuer_europa__klimaschutzziele_fuer_2030_sollten_angehoben_werden.html

Patterson, M., & Monroe, K. R. (1998). Narrative in political science. *Annual Review of Political Science*, *1*(1), 315–331. https://doi.org/10.1146/annurev.polisci.1.1.315

Pedersen, R. B. B., Alonso, A. R. P., Jensen, I. G., Ravn, H., & Münster, M. (2017). Modelling of renewable gas in the future energy system. *International Gas Union Research Conference (IGRC 2017)*. https://orbit.dtu.dk/en/publications/modelling-of-renewable-gas-in-the-future-energy-system

Pelda, J., Holler, S., & Persson, U. (2021). District heating atlas—Analysis of the German district heating sector. *Energy*, *233*, 121018. https://doi.org/10.1016/j.energy.2021.121018

Pelda, J., Stelter, F., & Holler, S. (2020). Potential of integrating industrial waste heat and solar thermal energy into district heating networks in Germany. *Energy*, *203*, 117812. doi: 10.1016/j.energy.2020.117812

Persson, U., & Werner, S. (2011). Heat distribution and the future competitiveness of district heating. *Applied Energy*, *88*(3), 568–576. https://doi.org/10.1016/j.apenergy.2010.09.020

Pesch, U. (2015). Tracing discursive space: Agency and change in sustainability transitions. *Technological Forecasting and Social Change*, *90*, 379–388. https://doi.org/10.1016/j.techfore.2014.05.009

Peters, G. P., Andrew, R. M., Canadell, J. G., Friedlingstein, P., Jackson, R. B., Korsbakken, J. I., Le Quéré, C., & Peregon, A. (2020). Carbon dioxide emissions continue to grow amidst slowly emerging climate policies. *Nature Climate Change*, *10*(1), 3–6. https://doi.org/10.1038/s41558-019-0659-6

Pierson, P. (2000). Increasing Returns, Path Dependence, and the Study of Politics. *American Political Science Review*, *94*(2), 251–267. https://doi.org/10.2307/2586011

Popovski, E., Aydemir, A., Fleiter, T., Bellstädt, D., Büchele, R., & Steinbach, J. (2019). The role and costs of large-scale heat pumps in decarbonising existing district heating networks–A case study for the city of Herten in Germany. *Energy*, *180*, 918–933. doi: 10.1016/j.energy.2019.05.122

Prognos, Öko-Institut, & Wuppertal Institut. (2021). *Klimaneutrales Deutschland 2045. Wie Deutschland Wie Deutschland seine Klimazieleschon vor 2050 erreichen kann. Zusammenfassung im Auftrag von Stiftung Klimaneutralität, Agora Energiewende und Agora Verkehrswende [How Germany How Germany can achieve its climate goals before 2050. Summary commissioned by Stiftung Klimaneutralität, Agora Energiewende and Agora Verkehrswende]*. https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_04_KNDE45/A-EW_209_KNDE2045_Zusammenfassung_DE_WEB.pdf

Rehner, R., & McCauley, D. (2016). Security, justice and the energy crossroads: Assessing the implications of the nuclear phase-out in Germany. *Energy Policy*, *88*, 289–298. https://doi.org/10.1016/j.enpol.2015.10.038

Rennkamp, B., Haunss, S., Wongsa, K., Ortega, A., & Casamadrid, E. (2017). Competing coalitions: The politics of renewable energy and fossil fuels in Mexico, South Africa and Thailand. *Energy Research & Social Science*, *34*, 214–223. https://doi.org/10.1016/j.erss.2017.07.012

Rettig, E. (2016). *The Impact of Natural Gas Discoveries on Israeli Politics, Socioeconomic Discourse, and Regional Perception*. https://library.fes.de/pdf-files/iez/13037.pdf

Rivoire, M., Casasso, A., Piga, B., & Sethi, R. (2018). Assessment of Energetic, Economic and Environmental Performance of Ground-Coupled Heat Pumps. *Energies*, *11*(8), 1941. https://doi.org/10.3390/en11081941

Roberts, J. C. D. (2017). Discursive destabilisation of socio-technical regimes: Negative storylines and the discursive vulnerability of historical American railroads. *Energy Research & Social Science*, *31*, 86–99. https://doi.org/10.1016/j.erss.2017.05.031

Rosenbloom, D., Berton, H., & Meadowcroft, J. (2016). Framing the sun: A discursive approach to understanding multi-dimensional interactions within socio-technical transitions through the case of solar electricity in Ontario, Canada. *Research Policy*, *45*(6), 1275–1290. https://doi.org/10.1016/j.respol.2016.03.012

Roulston, K., & Choi, M. (2018). Qualitative interviews. In U. Flick (Ed.), *The SAGE handbook of qualitative data collection* (pp. 233–249). Sage London.

Sabatier, P. A. (1988). An advocacy coalition framework of policy change and the role of policy-oriented learning therein. *Policy Sciences*, *21*(2–3), 129–168. https://doi.org/10.1007/BF00136406

Sabatier, P. A., & Weible, C. M. (2014). The Advocacy Coalition Framework: Innovations and Clarifications. In P. A. Sabatier (Ed.), *Theories of the policy process* (pp. 189–220). Westview Press.

Saerbeck, B. (2021). Worüber keiner reden will: Der bevorstehende Abschied vom Gasnetz [What no one wants to talk about: The imminent end of the gas grid]. *Agora Energiewende*. https://www.agora-energiewende.de/blog/worueber-keiner-reden-will-der-bevorstehende-abschied-vom-gasnetz/

Schirrmeister, M. (2014). Controversial futures—Discourse analysis on utilizing the "fracking" technology in Germany. *European Journal of Futures Research*, *2*(1), 38. https://doi.org/10.1007/s40309-014-0038-5

Schlager, E. (1995). Policy making and collective action: Defining coalitions within the advocacy coalition framework. *Policy Sciences*, *28*(3), 243–270. https://doi.org/10.1007/BF01000289

Schrems, I., Zerzawy, F., Hügemann, S., & Wieland, P. (2021). *Was Erdgas wirklich kostet: Roadmap für den fossilen Gasausstieg im Wärmesektor [What natural gas really costs: Roadmap for the fossil gas phase-out in the heating sector]. Studie 06/2021*. https://foes.de/publikationen/2021/2021-06_FOES_Roadmap_Gasausstieg.pdf

Schumann, D., Fischer, W., & Hake, J.-F. (2016). Use of coal and coal exit in Germany from the perspective of the population. *ET. Energiewirtschaftliche Tagesfragen*, *66*(6), 18–22. https://inis.iaea.org/search/search.aspx?orig_q=RN:47075188

Seto, K. C., Davis, S. J., Mitchell, R. B., Stokes, E. C., Unruh, G., & Ürge-Vorsatz, D. (2016). Carbon Lock-In: Types, Causes, and Policy Implications. *Annual Review of Environment and Resources*, *41*(1), 425–452. https://doi.org/10.1146/annurev-environ-110615-085934

Shanahan, E. A., Jones, M. D., & McBeth, M. K. (2011). Policy Narratives and Policy Processes: Shanahan/Jones/McBeth: Narratives and Policy Processes. *Policy Studies Journal*, *39*(3), 535–561. https://doi.org/10.1111/j.1541-0072.2011.00420.x

Shanahan, E. A., Jones, M. D., McBeth, M. K., & Radaelli, C. M. (2018). The narrative policy framework. In P. A. Sabatier (Ed.), *Theories of the policy process* (pp. 173–213). Westview Press.

Sieberg, U., Koch, M., & Uphoff, H. (2016). *Effizient Erneuerbar. Was jetzt zum Gelingen einer Erneuerbaren Wärmewende getan werden muss [Efficiently Renewable. What needs to be done to ensure the success of a renewable heat transition]*. https://www.bee-ev.de/fileadmin/Publikationen/Positionspapiere_Stellungnahmen/BEE/20161031_BEE-W%C3%A4rme-_und_K%C3%A4ltestrategie.pdf

Simoens, M. C., Fuenfschilling, L., & Leipold, S. (2022). Discursive dynamics and lock-ins in socio-technical systems: An overview and a way forward. *Sustainability Science*. https://doi.org/10.1007/s11625-022-01110-5

Smink, M. M., Hekkert, M. P., & Negro, S. O. (2015). Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies: Keeping sustainable innovation on a leash? *Business Strategy and the Environment*, *24*(2), 86–101. https://doi.org/10.1002/bse.1808

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy*, *41*(6), 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012

Sovacool, B. K., & Hess, D. J. (2017). Ordering theories: Typologies and conceptual frameworks for sociotechnical change. *Social Studies of Science*, *47*(5), 703–750. https://doi.org/10.1177/0306312717709363

Spitalny, L., Myrzik, J. M. A., & Mehlhorn, T. (2014). Estimation of the economic addressable market of micro-CHP and heat pumps based on the status of the residential building sector in Germany. *Applied Thermal Engineering*, *71*(2), 838–846. https://doi.org/10.1016/j.applthermaleng.2013.12.027

Statistisches Bundesamt, [Federal Statistical Office] & Destatis. (2014). *Bauen und Wohnen. Mikrozensus—Zusatzerhebung 2014. Bestand und Struktur der Wohneinheiten. Wohnsituation der Haushalte [Building and housing. Microcensus—Supplementary survey 2014. Stock and structure of housing units. Housing situation of households]*. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Wohnen/Publikationen/Downloads-Wohnen/wohnsituation-haushalte-2055001149004.pdf?__blob=publicationFile

Stephenson, E., Doukas, A., & Shaw, K. (2012). "Greenwashing gas: Might a 'transition fuel' label legitimize carbon-intensive natural gas development?" *Energy Policy*, *46*, 452–459. https://doi.org/10.1016/j.enpol.2012.04.010

Sterchele, P., Palzer, A., & Henning, H.-M. (2017). The role of heat pumps in the transformation of national energy systems-Example Germany. *Proc. 12th Int. Energy Agency Heat Pump Conf.* http://heatpumpingtechnologies.org/archive/hpc2017/wp-content/uploads/2017/05/PO.01-The-role-of-heat-pumps-in-the-transformation-of-national-energy-systems-Example-Germany.pdf

Strbac, G., Pudjianto, D., Sansom, R., Djapic, P., Ameli, H., Shah, N., Brandon, N., Hawkes, A., & Qadrdan, M. (2018). *Analysis of Alternative UK Heat Decarbonisation Pathways*. For the Committee on Climate Change. https://www.theccc.org.uk/wp-content/uploads/2018/06/Imperial-College-2018-Analysis-of-Alternative-UK-Heat-Decarbonisation-Pathways.pdf

Szabo, J. (2021a). Natural Gas' Changing Discourse in European Decarbonisation. In M. Mišík & N. Kujundžić (Eds.), *Energy Humanities. Current State and Future Directions* (pp. 67–88). Springer International Publishing. https://doi.org/10.1007/978-3-030-57480-2_5

Szabo, J. (2021b). Fossil Capitalism's Lock-ins: The Natural Gas-Hydrogen Nexus. *Capitalism Nature Socialism*, *32*(4), 91–110. https://doi.org/10.1080/10455752.2020.1843186

Triebs, M. S., Papadis, E., Cramer, H., & Tsatsaronis, G. (2021). Landscape of district heating systems in Germany – Status quo and categorization. *Energy Conversion and Management: X*, *9*, 100068. https://doi.org/10.1016/j.ecmx.2020.100068

UBA (Umweltbundesamt) [Federal Environment Agency]. (2020a). *13 Thesen für einen treibhausgasneutralen Gebäudebestand. Drängende Herausforderungen der Wärmewende [13 theses for a greenhouse gas neutral building stock. Urgent challenges of the heat transition]* [Position paper]. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/pp_13thesen_treibhausgasneutraler_gebaeudestand_bf.pdf

UBA (Umweltbundesamt) [Federal Environment Agency]. (2020b). *Bioenergie [bioenergy]*. https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/bioenergie#Reststoffe

UBA (Umweltbundesamt) [Federal Environment Agency] & co2online. (2019). *Wohnen und Sanieren. Empirische Wohngebäudedaten seit 2002 [Housing and refurbishment. Empirical residential building data since 2002]*. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-05-23_cc_22-2019_wohnenundsanieren_hintergrundbericht.pdf

Unnerstall, T. (2017). Three Targets of the Energy Transition: Description. In T. Unnerstall, *The German Energy Transition* (pp. 13–17). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-54329-0_2

Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy*, *28*(12), 817–830. https://doi.org/10.1016/S0301-4215(00)00070-7

Urhammer, E., & Røpke, I. (2013). Macroeconomic narratives in a world of crises: An analysis of stories about solving the system crisis. *Ecological Economics*, *96*, 62–70. https://doi.org/10.1016/j.ecolecon.2013.10.002

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study: Qualitative descriptive study. *Nursing & Health Sciences*, *15*(3), 398–405. https://doi.org/10.1111/nhs.12048

von Hirschhausen, C. R., Kemfert, C., & Praeger, F. (2020). *Fossil natural gas exit: A new narrative for European energy transformation towards decarbonization*. DIW Berlin, German Institute for Economic Research. https://www.iaee.org/eeep/eeepexec/eeep10-2-von%20Hirschhausen-exsum.pdf

Wachsmuth, J., Michaelis, J., Neumann, F., Wietschel, M., Duscha, V., Degünther, C., Köppel, W., & Zubair, A. (2019). *Roadmap Gas für die Energiewende: Nachhaltiger Klimabeitrag des Gassektors [Roadmap Gas for the energy transition: Sustainable climate contribution of the gas sector]*. Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-04-15_cc_12-2019_roadmap-gas_2.pdf

Weible, C. M., Sabatier, P. A., Jenkins-Smith, H. C., Nohrstedt, D., Henry, A. D., & DeLeon, P. (2011). A quarter century of the advocacy coalition framework: An introduction to the special issue. *Policy Studies Journal*, *39*(3), 349–360. https://doi.org/10.1111/j.1541-0072.2011.00412.x

Weiß, J., Dunkelberg, E., & Hirschl, B. (2018). Implementing the Heating Sector Transition in Our Cities—Challenges and Problem-Solving Approaches Based on the Example of Municipalities in Germany. In *Urban Energy Transition* (pp. 283–292). Elsevier. https://doi.org/10.1016/B978-0-08-102074-6.00029-2

Weiß, U., Stange, H., Beermann, Y., Werle, M., Braungardt, S., Köhler, B., Leopoldus, S., Seckinger, N., Ott, B., & Radgen, P. (2021). *Wärmewende: Die Energiewende im Wärmebereich. Überblick über internationale Erfahrungen [Heat transition: The energy transition in the heating sector. Overview of international experience]*. https://www.ifeu.de/publikation/waermewende-die-energiewende-im-waermebereich/

Willig, C., & Rogers, W. S. (2017). *The SAGE handbook of qualitative research in psychology*. Sage.

World Economic Forum. (2021). *Grey, blue, green – why are there so many colours of hydrogen?* https://www.weforum.org/agenda/2021/07/clean-energy-green-hydrogen/

Yakovenko, K., & Mišík, M. (2020). Cooperation and Security: Examining the Political Discourse on Natural Gas Transit in Ukraine and Slovakia. *Energies*, *13*(22), 5969. https://doi.org/10.3390/en13225969

Zanocco, C., Song, G., & Jones, M. (2018). Fracking Bad Guys: The Role of Narrative Character Affect in Shaping Hydraulic Fracturing Policy Preferences: Fracking Bad Guys. *Policy Studies Journal*, *46*(4), 978–999. https://doi.org/10.1111/psj.12278

Zhou, Z., & Qin, Q. (2020). Decoding China's natural gas development: A critical discourse analysis of the five-year plans. *Technological Forecasting and Social Change*, *151*, 119798. https://doi.org/10.1016/j.techfore.2019.119798

Zukunft Gas. (2021). *Klimaneutral Wohnen. Wie die CO_2-Minderung in Wohngebäuden gelingen kann [Climate neutral living. How CO_2 reduction in residential buildings can succeed]*. https://gas.info/fileadmin/Public/PDF-Download/Klimaneutral-Wohnen.pdf

Appendix A: Interview Guide

Disclaimer: This is a translated version as the interviews were held in German.

Interview Guide

1. Introduction

Introduction

- What is your role in ...?
- What are your tasks? How long have you been working in that area?
    - To what extent do you encounter the topic of natural gas in the building sector in your work?

Content and aim of the interview:

The study has the general objective to contribute to the understanding of how the heat transition in the building sector in Germany can be accelerated. More specifically, the focus is on the discourse on natural gas in the building sector. It will be analysed how different actors assess and portray the role and significance of natural gas, and which political measures are deemed necessary. Based on this, it will be discussed what implications that has on the heat transition in the building sector and to what extent discourses lead to the creation of 'carbon lock-ins' (i.e., technological, institutional, and behavioural path dependencies in fossil-based energy sources) arise or could arise. For this purpose, actors from the fields of politics, industry, as well as representatives of research institutes, think tanks and NGOs are interviewed and relevant documents are analysed.

2. Germany's heat transition in the building sector

- How can Germany successfully advance the heat transition in the building sector?
- In your opinion, which technologies and energy sources should play a role?
    - Why?
- What do you currently see as the greatest challenges for the heat transition in Germany?
- In your opinion - why has Germany (repeatedly) failed to meet its emission reduction targets in the building sector?

3. Role of (natural) gas

- How important do you consider the role of natural gas in the heat supply in Germany's building sector to be…
    - …currently?
    - …until 2030?
    - …by 2045 (climate neutrality target)?
- Do you think Germany should plan a phase-out of fossil natural gas in the building sector? By when?
- Why is a phase-out of fossil natural gas hardly (publicly) discussed?

- In your opinion, what are the advantages of using natural gas for the heating of buildings?
- In your opinion, what are the disadvantages of using natural gas for the heating of buildings?
- What do you see as the macroeconomic and political reasons for natural gas taking up such a large share of the heat supply?
- How realistic do you consider the potential of hydrogen and biogas to supply part of the heat supply in the building sector?
- Where do you see the potential for renewable energies in the heating sector, also with regard to economic value creation and job security?
- In your opinion, what political goals should be pursued for the heating in the building sector, especially with regard to natural gas?
- In your opinion, what political measures would be necessary and politically advisable to advance the heat transition in buildings, especially with regard to natural gas?

4. Lock-ins

- What do you think about the investments into new gas infrastructure in Germany, especially with regard to Germany's climate targets?
    - Over 650,000 new gas boilers were sold in Germany in 2021 - what risks do they see in this?
    - For maintenance and expansion of grids, approx. 3 billion € were invested in 2020 - what do you think about these investments, do you see risks?
- Do you see risks of creating carbon lock-ins with regard to gas?
    - If yes, to what extent?
    - How could these be prevented?

Appendix B: Interview Consent Form

Disclaimer: This is a translated version as the consent form was sent to the participants in German.

Information Participation and Data Handling - Master's Thesis Anna Kraus

This form is to ensure that you have received information about the research project and your participation and the handling of the data collected.

Aim of the study:
The study has the general objective to contribute to the understanding of how the heat transition in the building sector in Germany can be accelerated. More specifically, the focus is on the discourse on natural gas in the building sector. It will be analysed how different actors assess and portray the role and significance of natural gas, and which political measures are deemed necessary. Based on this, it will be discussed what implications that has on the heat transition in the building sector and to what extent discourses lead to the creation of 'carbon lock-ins' (i.e., technological, institutional, and behavioural path dependencies in fossil-based energy sources) arise or could arise. For this purpose, actors from the fields of politics, industry, as well as representatives of research institutes, think tanks and NGOs are interviewed and relevant documents are analysed.
Participation and data handling:
Your participation is voluntary, and you have the right to withdraw your participation at any time without giving reasons. During the interviews, you do not have to answer all the questions asked and you have the opportunity to ask follow-up questions at any time if the content or purpose of the question is unclear. You also reserve the right to refuse or cease participation in the interview process without stating your reason and may request to keep certain materials confidential. At any stage of the research (until 5 May 2022) you, as a research participant, have the right to access your own personal data, to request its rectification or erasure, or to request that the processing of data be restricted. There are no anticipated risks to individuals taking part in this study.
The audio tracks of the interviews will be recorded and subsequently transcribed, or notes will be taken. The data collected will be analysed as part of the research project. The participants remain anonymous, and the data collected cannot be traced back to a participant. The participants are only referred to as actors of a respective actor group (e.g. 'actor environmental research institute'). Thus, no statements are made about specific participants and their organisations, but the level of analysis remains on actor groups. All data will be handled in accordance with Lund University guidelines. Interview data will be stored and analysed using a participant number which will be recorded in a separate document. All research materials, including participant data, are stored password protected and are only accessible to the researcher. The data will not be shared with third parties. Interview data will be saved for a limited time after the research is completed to validate the research findings.
The findings of this study will be written up as an M.Sc. thesis and presented in an internal thesis defence. A final version of the thesis will be published in the university's open-access database in autumn 2022 (online accessible here: https://www.iiiee.lu.se/education/masters-programme-environmental-management-and-policy-emp/msc-theses-iiiee).

For any questions please contact:
Anna Kraus
M.Sc. Environmental Management & Policy
International Institute for Industrial Environmental Economics, Lund University

Appendix C: Overview of Conducted Interviews

Actor	specifications	# of interviews
national state actors	Respondent 1, national state actor, member of Bundestag	3
	Respondent 2, national state actor, member of Bundestag	
	Respondent 3, national state actor, member of ministry	
gas industry associations	Respondent 4, gas industry association	3
	Respondent 5, gas industry association	
	Respondent 6, gas industry association	
gas network operators	Respondent 7, gas network operator (supra-regional gas transmission operator)	2
	Respondent 8, gas network operator (supra-regional gas transmission operator)	
energy suppliers	Respondent 9, regional energy supplier	2
	Respondent 10, regional energy supplier association	
environmental NGOs	Respondent 11, environmental NGO	2
	Respondent 12, environmental NGO	
environmental research institutes and think tanks	Respondent 13, environmental research institute	2
	Respondent 14, environmental think tank	
renewable heating industry associations	Respondent 15, renewable heating industry association	2
	Respondent 16, renewable heating industry association	
total		**16**

Appendix D: Overview of Documents Reviewed

Actor group	Document title	Type of document
Environmental NGOs	Greenpeace Germany (2021): Factsheet: Fossiles Gas [Factsheet: natural gas]	Factsheet including policy demands
	FOES (2021): Was Erdgas wirklich kostet: Roadmap für den fossilen Gasausstieg im Wärmesektor [What natural gas really costs: Roadmap for the fossil gas phase-out in the heating sector]	Roadmap/policy paper
Environmental research institutes and think tanks	Agora Energiewende (2021): Worüber keiner reden will: Der bevorstehende Abschied vom Gasnetz [What no one wants to talk about: the imminent end of the gas grid]	Blog article including policy demands
	DUH[3] and DIW (2021): Am Klimaschutz vorbeigeplant - Klimawirkung, Bedarf und Infrastruktur von Erdgas in Deutschland: Hintergrundpapier [Planning past climate protection - Climate impact, demand and infrastructure of natural gas in Germany. Background paper]	Background paper/policy advisory
Renewable heating industry associations	BWP (2021): Roadmap Wärmepumpe. Der Weg zur Dekarbonisierung des Gebäudesektors [Roadmap heat pump. The pathway to decarbonise the building sector]	Roadmap/policy paper
	BEE (2021): Legislatur der Wärme – Was jetzt zu tun ist [Legislature of heat – What needs to be done now]	Background paper/policy advisory
Gas industry associations	Zukunft Gas (2021): Klimaneutral Wohnen. Wie die CO_2-Minderung in Wohngebäuden gelingen kann [Climate neutral living. How CO_2 reduction in residential buildings can succeed]	Background study including policy demands
	BVEG (2022): Wie Erdgas zum Klimaschutz beiträgt [How natural gas contributes to climate protection]	Background information
	BDEW (n.d.-b): Wärmewende mit Gas [Heat transition with gas]; and (n.d.-a): Die Rolle von Erdgas in der Energiewende [The role of natural gas in the energy transition]	Background information including policy demands
Energy suppliers	E.ON (2020): Energiewende mit grünem Gas kommt einkommensschwachen Haushalten zugute [Energy transition with green gas benefits low-income households]	Background study including policy demands
Gas network operators	FNB Gas (2021): The value of hydrogen in the heating market. An analysis of different heating technologies with a focus on hydrogen condensing boilers and electric heat pumps	Background study including policy demands
National and regional state actors	*Because of the wide range of different state actors and the major differences between the positions of different parties, no documents of state actors were included.*	

[3] The DUH is an environmental NGO, and the DIW is a research institute. Thus, this paper could be allocated to either one of the two categorisations.

Appendix E: Coding Framework