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ORIGINAL ARTICLE

Local heat transitions—a comparative case study of five bioenergy villages in Northern and Southern Germany

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Abstract Although the heat transition is one of the greatest challenges that Germany faces in terms of its climate and sustainability goals, local initiatives that target a renewable heat transition remain contested. In the present article, we examine bioenergy villages and investigate both how and under what conditions these villages can contribute to the heat transition. We explore five typical bioenergy villages in Mecklenburg-Vorpommern and three typical bioenergy villages in Baden-Württemberg. Drawing on the analytical framework of actor-centred institutionalism, we adopt a dual perspective by focusing on both actors and institutions. In our interviews, local farmers and mayors are identified as key actors in bioenergy villages. We argue that the main contributions of these local entrepreneurs to heat transitions involve increasing social acceptance of new ecological heat infrastructures and technologies, fostering democratic governance, and supporting regional added value and learning.

Keywords Bioenergy village · Comparative case study · Germany · Heat transition · Local governance · Renewable energies · Policy entrepreneurs

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Lokale Wärmewenden – Eine vergleichende Analyse von fünf Bioenergiedörfern aus Nord- und Süddeutschland

Zusammenfassung Obwohl die Wärmewende eine der größten Herausforderungen für Deutschland im Hinblick auf seine Klima- und Nachhaltigkeitsziele ist, bleiben lokale Initiativen für eine erneuerbare Wärmewende umstritten. Vor diesem Hintergrund beschäftigt sich dieser Artikel mit Bioenergiedörfern und fragt: Unter welchen Bedingungen und wie können Bioenergiedörfer zur Wärmewende beitragen? In einer explorativen Fallstudie untersuchen wir fünf typische Bioenergiedörfer in Mecklenburg-Vorpommern und drei Bioenergiedörfern in Baden-Württemberg. Mit dem Akteurszentrierten Institutionalismus als analytischen Rahmen, nehmen wir eine doppelte Perspektive auf Akteure und Institutionen ein. Basierend auf den Ergebnissen der Interviews identifizieren wir lokale Landwirte und Bürgermeister*innen als Schlüsselakteure für Bioenergiedörfer. Wir argumentieren, dass die wichtigsten Beiträge dieser Policy Entrepreneure zur Wärmewende darin bestehen, die soziale Akzeptanz neuer ökologischer Wärmeinfrastrukturen und -technologien zu erhöhen, eine Demokratie zu fördern und die regionale Wertschöpfung sowie Lernprozesse zu unterstützen.

Schlüsselwörter Bioenergiedörfer · Vergleichende Fallstudie · Deutschland · Wärmewende · Lokale Governance · Erneuerbare Energien · Policy Entrepreneure

1 Introduction

Transforming energy systems in order to reduce CO_2 emissions and prevent the worst consequences of climate change for humanity is one of the greatest global challenges of our time. With the June 2021 amendment to the Climate Protection Act, Germany decided to reduce its CO_2 emissions by 65% by 2030 (compared with 1990) and to aim for net-zero emissions by 2045. While the share of renewable energy in the electricity sector was at 46.2% in 2022, renewable energy only constituted 17.4% of the heating sector (AGEE-Stat 2023). This observation illustrates the crucial role that the heating sector plays in achieving Germany's climate targets. However, the heat transition—that is, the transformation from a fossil-based heat supply to a sustainable, renewable supply—has received much less academic and public attention. The present paper thus aims to address and fill this gap by examining local heat transition initiatives.

At the local level, initiatives that aim at a renewable heat transition—especially bioenergy villages—have become more common over the last two decades (Grundmann and Ehlers 2016; Roesler and Hassler 2019). These initiatives can be seen as pioneers in the heat transition because bioenergy plays a dominant role in the heating sector and accounts for the largest share of renewable energy (BMEL 2022). Residents of bioenergy villages are supplied with biomass-based heat via district heating networks. These villages cover at least 50% of their energy demand with regionally produced bioenergy, though other forms of renewable energy can be added. In order to be formally recognized as a bioenergy village by the Agency for Re-

newable Raw Materials (in German: Fachagentur Nachwachsende Rohstoffe; FNR), the energy plants must be at least partially owned by heat costumers and farmers. In addition, citizens must be actively involved in decision-making processes. This decentralized climate action therefore also contributes to regional value creation and citizen participation (Gailing 2018, p. 83).

With the 2021 coalition agreement to push for a German heat transition (SPD, Bündnis 90/Die Grünen, FDP 2021, pp. 45–49) as well as the latest report from the Intergovernmental Panel on Climate Change—which demands immediate climate action at all political levels (IPCC 2023)—and the rapid changes to Germany's energy architecture that were brought about by the Russian invasion of Ukraine in February 2022 in order to ensure energy security, bioenergy villages have now taken centre stage. At the same time, more and more bioenergy villages are approaching the end of the 20-year funding period with fixed feed-in tariffs that are guaranteed by the Renewable Energy Act. This situation has been discussed as a challenge for bioenergy villages, which have thus far benefitted from the ability to keep their heat prices very low (Bruch-Krumbein 2020; Wilkens et al. 2020). Due to these multi-level dynamics, the role that bioenergy villages can play in Germany's heat transition is contested. In the present paper, we seek to better understand current developments in local climate action and to contribute to the debate on the interplay between agencies and institutions that are rethinking policy entrepreneurship at the local level (Capano and Galanti 2021; Eckersley and Lakoma 2022; Mintrom and Luetjens 2017). We thereby investigate both *how and under what conditions bioenergy villages can contribute to the German heat transition against the backdrop of the above-outlined developments.*

We examine five bioenergy villages that represent a diversity of socio-economic and geographical settings. Previous studies on bioenergy villages have mainly focused on techno-economic or institutional elements (Jenssen et al. 2014; McCormick and Kaberger 2007; Oteman et al. 2014; Petersen 2016). Although these publications underline the importance of non-technical issues and actor dynamics, the various contributions that bioenergy villages can make to heat transitions through specific actor interactions are not yet well understood. Our study thus aims to provide useful groundwork towards theory-building concerning this under-researched topic. Therefore, we seek to gather more knowledge on what is happening between actors and institutions in local communities in order to gain a better understanding of the causal mechanisms and factors that lead to the successful implementation of bioenergy villages beyond technical elements.

By drawing on the analytical framework of actor-centred institutionalism (Mayntz and Scharpf 1995), we focus on the interaction of actors within institutional structures in order to identify success factors for bioenergy villages (Sect. 2). Our analysis is based on 16 guided expert interviews that were conducted between April and June 2022 (Sect. 3). We demonstrate that bioenergy villages rely on national (and state) frameworks for funding and support as well as on favourable prices and discursive settings (Sect. 4). At the same time, the agency in charge of effective implementation and local innovation should not be underestimated. We therefore identify and discuss the various contributions of local actors to the heat transition, including the increasing acceptance of new ecological heat infrastructures and technologies,

which have led to increased participation and regional added value (Sect. 5). We additionally highlight the policy entrepreneurship of mayors and farmers in bioenergy villages and argue that these villages have distinctive features that should be tested in further studies in order to better define local policy entrepreneurs. Hence, with this exploratory multiple-case study, we complement the existing state of research on bioenergy villages (e.g. Grundmann and Ehlers 2016; Roesler and Hassler 2019) and identify patterns of local policy entrepreneurs in local energy transitions (e.g. Baasch 2021; Fuchs and Hinderer 2016; Purkus et al. 2018).

2 The interplay between actors and institutions

The local level of government is the lowest level in Germany's federal architecture and includes both municipality administrations and district administrations. While the local level has traditionally been studied in terms of policy implementation and public service provision, recent analyses have highlighted the increasing importance of the local level as an arena for people to orientate and shape their lives (Möltgen-Sicking 2019, p. 24) and to develop innovative solutions for public goods, including for climate change mitigation and adaptation as well as for renewable energy (Bulkeley and Kern 2006; Haupt et al. 2022; Verdujin 2016; Zeigermann et al. 2023).

We use the actor-centred institutionalism of Renate Mayntz and Fritz Scharpf (1995) as an analytical framework to account for the interplay between bottom-up agency and top-down political funding schemes and rules at the subnational level. The ACI "conceptualizes policy processes driven by the interaction of individual and corporate actors endowed with certain capabilities and specific cognitive and normative orientations within a given institutional setting and within a given external situation" (Scharpf 1997, p. 37). Accordingly, our underlying assumption is that the success of bioenergy villages can be explained as the outcome of interactions among diverse and interdependent local actors but that the horizontal and vertical interactions of these villages are structured—and their outcomes are shaped—by the characteristics of the institutional settings in which they occur (Fürst 2010, pp. 53–54; Scharpf 1997, p. 1).

Following Scharpf's concept of institutions as "systems of rules that structure the courses of actions that a set of actors may choose" (Scharpf 1997, p. 38), the Renewable Energy Act (REA), bioenergy funding schemes, and norms—such as Germany's commitment to both greenhouse gas reduction and the energy transition—can be seen as important determinants of local actors and of the scope of their interactions (Mayntz and Scharpf 1995, p. 45). Indeed, national and European decisions and funding play an important role at the subnational level (Knodt and Ringel 2019; Solorio and Jörgens 2020; Zeigermann et al. 2023). Therefore, a multi-level governance perspective is needed to contextualize and explain the current local dynamics in bioenergy villages. At the same time, we argue that a contested policy setting leaves room for divergent ideas of how best to solve a problem (Scharpf 1997). This situation opens the floor for local actors to engage in entrepreneurial actions that can change policy practices and can connect the top-down (institutional) and bottom-up (participatory) levels (Böcher 2016).

Our analysis focuses on a wide range of local actors from politics, administration, private businesses, and civil society organizations as well as on the interactions between these actors. According to the ACI, actors are characterized by their capabilities and orientations, which allow them to influence outcomes to a certain extent (Scharpf 1997, p. 43). The ACI points out that policy outcomes are not achieved by one local actor alone. Therefore, the constellation of actors involved in horizontal and vertical interactions is important when it comes to explaining local outcomes (Scharpf 1997, p 44; Fürst 2010). The actor constellation describes a static picture with the actors involved, their strategic options, their preferences, and any associated outcomes (Scharpf 1997, pp. 44–45). While studies have analysed citizen participation in bioenergy villages (Gailing 2018, p. 83), little remains known about the specific characteristics and constellations of actors that determine the contribution of bioenergy villages to the heat transition in Germany. This is particularly true for actors that stand out in such constellations—that is, as policy entrepreneurs.

Studies on regional processes underline the role of special actors that have characteristic features of policy entrepreneurs[1] (Böcher 2016). For example, Benz et al. (1999) identified key actors in regional governance processes and noted that these actors may include individuals or firms that initiate regional cooperation through organizing, moderating, and steering activities. Petridou (2018) refers specifically to professional administrators in Swedish municipalities who act entrepreneurially as agents of innovation. Perkmann (2003, 2007) and Eckersley and Lakoma (2022) have also stressed the importance of policy entrepreneurship in stimulating regional governance processes. Furthermore, Fürst, Lahner, and Pollermann (2006) distinguish between different types of promoters that can mobilize and coordinate other local actors. Drawing on these studies, Böcher (2016) argues that it is fruitful to use policy entrepreneurship as a concept for better understanding how and why some actors are able to exert influence in subnational policy processes.

Böcher identifies four main functions of regional policy entrepreneurs: (1) investing personal resources in order to build alliances, (2) using the pressure of regional problems to open a window of opportunity, (3) acting as process promotors that develop innovative strategies and contribute to their realization, and (4) using different power resources (e.g. political experience, professional reputation, or expertise) to realize new ideas (Böcher 2016, p. 149). By considering policy entrepreneurship as an independent variable that can be used to explain local heat transitions, we seek to advance the ACI, which has mainly been used to study policy processes at the national, transnational, and EU levels. We aim to identify policy entrepreneurs in bioenergy villages and to understand how these entrepreneurs interact within specific constellations and institutional settings in order to generate a heat transition that

[1] Researchers have long discussed the role and characteristics of policy entrepreneurs as key actors who are crucial to achieving policy change (Ackrill and Kay 2011; Faling et al. 2019; Kingdon 1984; Mintrom and Norman 2009; Mintrom and Vergari 1996). Policy entrepreneurs are "risk-takers" (Brouwer and Biermann 2011) who develop ideas and contribute to their implementation. They mobilize the public, develop actor coalitions, and are willing to invest money, labour, and time in order to advance their ideas in the face of criticism (Roberts and King 1991). They know that ambitious goals—such as the heat transition—require framing a problem, having a solution ready, and ensuring that policymakers support this solution (Cairney 2018).

benefits all actors in the community and that also contributes to Germany's overall emission reduction goals.

3 Methodology

The present paper contributes to the discussion on local heat transitions by exploring the interaction of actors and institutions in bioenergy villages via a qualitative in-depth exploratory multiple case study design. Exploratory case studies are suitable when "investigat[ing] distinct phenomena characterized by a lack of detailed preliminary research" (Mills et al. 2010, p. 372). Given the persistent "black box" that encompasses the role of local actor constellations and entrepreneurship in the heat transition outlined above, we use a research design and methods that allow us to generate hypotheses (Mills et al. 2010; Yin 2014). The data examined in this paper (see 3.2) are part of a larger qualitative study on bioenergy villages in which 16 in-depth semi-structured interviews were conducted with representatives of five bioenergy villages in the spring of 2022.

3.1 Studying bioenergy villages

We focus on bioenergy villages that are registered with the Agency for Renewable Raw Materials in order to ensure that our cases meet the following criteria:

- At least 50% of the energy demand must be covered by bioenergy that is produced regionally, thereby increasing the local added value.
- Citizens must be involved in the decision-making process and must actively support the idea of the bioenergy village.
- Bioenergy plants must be at least partially owned by heat customers or local farmers.
- Measures of energy efficiency and energy saving must be regularly reviewed and implemented.
- Other forms of renewable energy can also be used (FNR 2023).

We take the fulfilment of these criteria as an indicator of the contribution of a bioenergy village to the German heat transition, which is examined in detail below. Given the exploratory nature of our study, the selection of cases was based on the similarity of the dependent variable (Lauth et al. 2015, pp. 65–66). The independent variables are the conditions that led a bioenergy village to contribute to the heat transition, which are represented by actors and institutions (as explained in Sect. 2).

For the case selection, two different federal states were chosen in order to analyse possible influences at the regional level. Baden-Württemberg and Mecklenburg-Vorpommern were of particular interest as they differ significantly not only in terms of structural characteristics, but also in terms of the number of existing bioenergy villages, as shown in Table 1.

In a second step, we identified typical bioenergy villages in Mecklenburg-Vorpommern (Northern Germany) and Baden-Württemberg (Southern Germany) using

Table 1 Regional structure of the bioenergy villages

	Mecklenburg-Vorpommern*	Baden-Württemberg**
State CO_2 reduction goals	Climate neutrality by 2040	Climate neutrality by 2040 Greenhouse gas emissions reduced by at least 65% by 2030 compared with 1990
Supportive political strategies	Climate Protection Action Plan Mecklenburg-Vorpommern (2010) Energy policy concept for Mecklenburg-Vorpommern (2015)	Climate Protection Act of 2013 (amended in 2020 & 2021), which was developed into the Climate Protection and Climate Change Adaptation Act (2023) Integrated Energy and Climate Protection Concept Baden-Württemberg (2014), which was developed into the Climate Measures Register (2022) State concept combines heat and power generation in Baden-Württemberg (2015) Immediate action program for climate protection and energy transition (2021)
Funding for bioenergy villages	Climate protection funding guideline for municipalities (current version, 2014) Climate protection funding guideline for companies Regenerative energy supply funding guideline	Funding program "Bioenergy Competition" (2007) and "Bioenergy Villages" (2010) Funding program "Energy-Efficient Heat Grids" (2017–2023) replaced the funding program "Bioenergy Villages"
N° of bioenergy villages	8	56
GDP per Capita 2022	€32,837	€50,982

Sources: FNR (2023a); Statistisches Bundesamt (2023); *Information from Ministry for Climate Protection, Agriculture and Rural Areas and Environment Mecklenburg-Vorpommern (2023); **Information from Ministry for the Environment, Climate and Energy Industry Baden-Württemberg (2023a, b, c), Landtag Baden-Württemberg (2012)

the FNR database, which contains datasheets on all registered bioenergy villages. Four criteria were defined for the selection of typical cases:

- The bioenergy village must have or have had a biogas plant.
- The biogas plant must have been commissioned before 2012.
- The number of residents in the bioenergy village must range from 300 to 2300.
- The bioenergy village must be located in different districts.

Based on the availability of data as well as the availability and willingness of interview partners, five bioenergy villages were subsequently selected. Table 2 provides an overview of the FNR criteria as well as the sociodemographic and geographic characteristics of the selected bioenergy villages. While Rosenow and Bollewick are located in Northern Germany, Lampertsweiler, Wolpertshausen, and Mauenheim are located in Southern Germany.

Table 2 Characteristics of the bioenergy villages selected for our comparative case study

Selected bioenergy villages/ characteristic features	Rosenow	Bollewick	Lampertsweiler	Wolpertshausen	Mauenheim
Heat technologies	Biogas plant + CHP plant (550 KWh) Heat storage Solar thermal energy Redundancy (gas boiler)	2 biogas plants + CHP plants (900 KWh)	Biogas plant + CHP plant (300 KWh) Wood chipping plant (300 KWh)	Wood chipping plant (840 KWh) Heat storage Shut-down biogas plant Geothermal energy Municipal district Hörlebach: Biogas plant + CHP plant (350 KWh)	Biogas plant + CHP plant (600 KWh) Wood chipping plant (900 KWh) Heat storage
Bioenergy village since	2015	2012	2010	Unknown	2006
Commissioned	Biogas plant: 2011 Heat grid: 2014	Biogas plants: 2010 & 2011 Heat grid: 2013	Biogas plant: 2003 Wood chipping plant: 2009	Biogas plant: 1995–2009 Wood chipping plant: 2009 Municipal district Hörlebach: Biogas plant: 2011	Biogas plant: 2005 Heat grid: 2006
Energy producer/ owner of the renewable energy plant	Farmer	Farmers	Farmer & agricultural dealer	Ökoprojekte Gronbach GmbH Municipal district Hörlebach: farmer cooperative	KCH Biogas GmbH (farmers; project developer: Clean Energy GmbH)
Operator/owner of the heat grid	Landwerke Rosenow GmbH (municipality & Wärmeversorgung Stavenhagen GmbH)	Wärmeversorgung Stavenhagen (operator) Municipality (owner)	Farmer & agricultural dealer	Ökoprojekte Gronbach GmbH Municipal district Hörlebach: farmer cooperative	Solarcomplex AG
Length of the heat grid	3.6 km	3.5 km	2 km	4.7 km	4 km
Connection rate	70%	70%	80%	60–70% Municipal district Hörlebach: 99%	90%

Sources: FNR database (2023a), supplemented with information from the interviews

3.2 Data collection and analysis

The data for the comparative case analysis stem mainly from semi-structured expert interviews. We interviewed local and regional stakeholders who play an active role in the respective bioenergy villages and therefore have specific knowledge about local processes and conditions that determine their village's contribution to the heat transition. In order to increase the validity of our results, at least three interviews were conducted in each bioenergy village. Typical interviewees included local politicians, farmers, and local business actors. In total, 16 interviews were conducted via telephone and the online communication tool Zoom between April and June 2022. The interviews were recorded and transcribed. Interviewees and data were anonymized. The interview guide consisted of six thematic sections, including questions about the respective interviewee and general information about the bioenergy village, the institutional context, relevant actor constellations, situational elements, perceived obstacles and success factors, and the interviewees' future perspectives regarding the bioenergy village.

For the transcribed interviews, we conducted a qualitative content analysis using a deductive-inductive approach in line with Mayring (2016). Hence, we combined Mayring's procedural models for structuring content analysis and inductive category development. The analysis was conducted using MAXQDA computer-assisted software. In a first step, main categories and subcategories were developed based on the framework of the ACI and the interview guide. Definitions, anchor examples, and coding rules were developed for each category. Subsequently, the first test run was carried out based on selected interview material in which the categories were assigned to the text passages. After coding about 30% of the material, the category system was adapted and revised. In addition to these interviews and in order to validate the interview data, we also studied relevant public documents, such as case studies of German bioenergy villages conducted by the FNR and the European Commission, newspaper articles, and homepages of the bioenergy village initiatives.

4 Understanding processes in local heat transitions

This section presents the findings of our analysis. We demonstrate that the success of a bioenergy village is determined by the structural setting (4.1) in which its diverse actors interact (4.2). Within this institutional framework, farmers, mayors, and corporate actors can act as local entrepreneurs (4.3).

4.1 Structures that determine actor interactions

Local dynamics in bioenergy villages are embedded in multi-level structures and are linked to both state and federal institutions. In the following section, we examine in greater detail how local actors interact with institutions at different political levels.

The interviews highlight the role that the specific settlement structure plays in the development of bioenergy villages. For example, we found that both a compact settlement structure and municipally owned properties—such as town halls,

swimming pools, and schools—are beneficial when it comes to the use of the heat grid. Rosenow, for instance, was found to benefit from a partially existing heat grid that only needs to be expanded. The interviewees also stressed that old oil heating systems in need of modernization are advantageous when bioenergy villages aim to convince stakeholders of the need for a new system. Furthermore, the availability and ownership of agricultural land and forest areas were found to be decisive criteria in the success of the bioenergy villages because the land is needed for the location of the biogas or wood chipping plants and for the substrate required for the operation of these plants. However, the settlement structure was also found to be capable of posing specific challenges for bioenergy villages. For example, Rosenow is located in a European bird sanctuary, which requires an environmental impact assessment, including an expensive species protection report.

The positive role of the national Renewable Energy Act was stressed in the interviews in every bioenergy village that relies on biogas plants. The Renewable Energy Act (REA) is the main government incentive structure that provides investment security through the guaranteed feed-in tariff and various bonuses, such as a bonus for combined heat and power generation. According to most interviewees, the low heat price—which is guaranteed by the REA—was the main driver behind citizens' initial decision to connect their homes to the heating system. Over the years, however, the Renewable Energy Act has been amended. As a result, the bioenergy villages have had to adapt, as is illustrated by the following quote: "*We thought that we could build a biogas plant, have the REA for 20 years, and that everything would be safe and plannable. But we learned that hardly anything is as flexible as biogas [funding]*" (Interview Rosenow).

Nevertheless, the actors from Bollewick, Rosenow, Wolpertshausen-Hörlebach, and Mauenheim were optimistic about the continued operation of the biogas plants after the end of the 20-year guaranteed feed-in tariff. Most of these interviewees had already invested in the flexible operation of bioenergy plants which is legally required for receiving ten-year follow-up remuneration through a tender procedure introduced by the 2017 REA. The combined heat and power stations—as well as the electricity and heat storages—allow for demand-responsive electricity generation. In addition, all bioenergy villages have benefited from further federal funding. In all cases, national funding for the heat grid and house connections is provided through the Kreditanstalt für Wiederaufbau (a state-owned promotional bank) and the Federal Office for Economic Affairs and Export Control (only Mauenheim did not receive funding from the latter organization). The interviewees additionally stressed the importance of such financial support for the implementation and development of their projects.

The bioenergy villages in Mecklenburg-Vorpommern receive additional funding for a heat grid, technology, storage, and planning through a state program that is supported by EU funds. As one farmer noted, "*The Landesförderinstitut [i.e. the regional funding institute] has […] funded our technology, pumps, and so on. […] That's nice money, and we wouldn't be able to realize the project without it*" (Interview Rosenow). In Baden-Württemberg, only Mauenheim receives financial support from the federal state for the woodchip boiler. State funding therefore seems to play an important yet subordinate role compared with federal funding in terms

of the contribution of bioenergy villages to the heat transition. We found that although interviewees generally described applying for funding as being complicated all bioenergy villages were found to benefit from federal and state incentive structures. Hence, these overarching funding schemes can be concluded to be essential to the success of local heat transitions. Local stakeholders actively engage with these state and federal institutions and use them to implement their projects. In some cases (e.g. Wolperthausen, Rosenow), the application for the funding is left to an experienced planning office or to a regional bank.

In addition to renewable energy acts and funding instruments, environmental and plant safety regulations—such as the Federal Immission Control Act—were mentioned by interviewees as being important for the approval and operation of local biogas plants. For example, fast certification as well as the approval of the woodchip heating plant and the biogas plant were found to be able to significantly accelerate local initiatives (Interview Mauenheim). However, according to the interviewees, the regional level—especially in Northern Germany—often delays these processes. The following quote criticizes the lack of support from the state level: "*Unfortunately, the implementation didn't go as we had imagined because state actors were sceptical about whether this was the right way [forward]. They believed municipalities shouldn't become economically active, and in my opinion, they tried to prevent it*" (Interview Bollewick).

Interviewees complained that complex bureaucratic requirements and personnel problems in public administrations had delayed the start of the renewable heat supply. Several interviewees further criticized the fact that increasing bureaucratic requirements were making the operation of bioenergy plants more difficult: "*These are things where you think, 'If we had known this in 2005, we might not have built it [i.e. the biogas plant] at all'*" (Interview Mauenheim). According to new environmental and plant safety standards, Lampertsweiler and Wolpertshausen had to install additional filters for the woodchip plants. In Wolpertshausen-Hörlebach, an emergency basin has to be built in order to meet the requirements of the Federal Immission Control Act, and in Mauenheim, a wall has to be built around the biogas plant in order to comply with water protection regulations. Moreover, the implementation of a local heat transition was described as a form of emancipation for local actors and as being the subject of a constant "*political fight*" (e.g. Interviews Bollewick, Rosenow, Lampertsweiler).

4.2 Actor constellations and interactions in bioenergy villages

Our analysis highlights the fact that relevant local actors in bioenergy villages include farmers, private or municipal companies and administrations, political actors such as mayors and local councils, and citizens.

- First, farmers were identified as important stakeholders because they own agricultural land and livestock and thus have the necessary space and substrate for the operation of biogas plants. Our interviews indicated that local bioenergy production is often associated with high-value-added activities for farmers.

- Second, the interviewees pointed to the technical know-how and human resources of small and medium-sized private or municipal companies as crucial resources for the successful management of bioenergy villages. In Wolpertshausen, for instance, energy production and the operation of the heat grid are organized by a company whose managing director was described as a "*biogas pioneer*". Another example is Bollewick, where an experienced and dedicated project engineer was identified as a central figure in local heat transitions. Furthermore, a regional municipal heat supplier was identified as an important stakeholder in the two bioenergy villages of Bollewick and Rosenow because the supplier operates or co-owns the local heat grids. In Mauenheim, regional companies were also identified as key actors: A consulting and project development company co-owns the biogas plant, and another company owns and operates the heat grid. These local or regional companies are profit-oriented but also often have strong ecological motivation to support bioenergy villages. In Mauenheim, in particular, regional companies are committed to the energy transition and are involved in the implementation of several bioenergy villages in the region. Our analysis therefore shows that in cases in which synergies for local added value and climate protection were identified, these businesses were found to play a key role in local actor constellations by bringing in networks as well as money, technology, know-how, and management experience to local heat transitions.
- Third, political and administrative actors were mentioned as important stakeholders in all biodiversity villages. Municipalities were found to be able to apply for the various renewable energy funding schemes and were also found to provide concession contracts that allow for the installation of heat pipes in public spaces. These pipes are necessary for all bioenergy villages, as the following quote highlights: "*[…] [I]f you want to lay heating pipes on public land, political support is basically a prerequisite*" (Interview Mauenheim). The municipality can also contribute to the success of the project by connecting public buildings such as schools, city halls, or hospitals to the grid. In public-private partnerships, municipalities can additionally partner with local businesses. In all cases, overlap was found between economic and political actors. For example, in Bollewick, Rosenow, Wolpertshausen, and Mauenheim, important economic actors also hold political offices, for instance, by serving as deputy mayors or local representatives. This finding is illustrated by the following quote: "*And we were lucky that the head of the village at the time […] very actively supported the project. However, he was also one of the shareholders of this biogas plant, so he also had a healthy self-interest in this project taking place*" (Interview Mauenheim). The professional understanding of bioenergy villages as opportunities for regional added value and energy independence as well as for providing attractive living conditions allows political actors with an economic background to convince other members of the local council about the benefits of these new projects. This dual role is possible because membership in the local council and the position of mayor are generally voluntary.
- Fourth, citizens—including people of all ages who live in a community and consume energy and heat for their homes from the local grid—are important local stakeholders in bioenergy projects. By deciding for or against their connection to

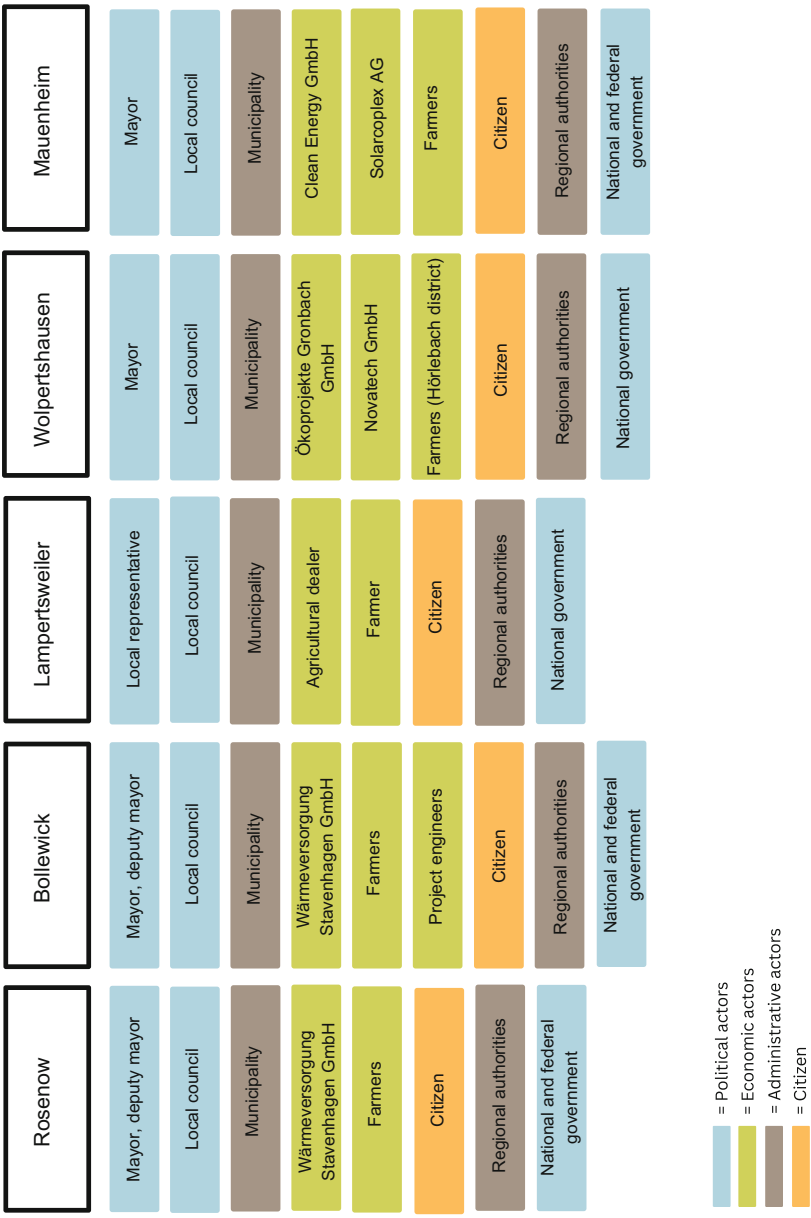

Fig. 1 Actor constellations in bioenergy villages (own table; based on interviews)

the heating network, citizens can make a significant contribution to this network's success or failure. If the heating network is not fully utilized, it cannot operate efficiently. While not all citizens are equally involved in the local initiative, their general support of—and participation in—the bioenergy heating project is essential to its success.

- Fifth, regional and national authorities were also identified as important actors in the realization of heat transitions. The multi-level interaction of actors and their complex constellation therefore appears to be a characteristic feature of these transitions.

Figure 1 provides an overview of the various actors in Rosenow, Bollewick, Lampertsweiler, Wolpertshausen, and Mauenheim that are involved in the bioenergy project.

In most cases, the actors were initially sceptical about the biomass-based local heating supply. For instance, citizens feared that the project would lead to a maize monoculture and to unequal benefits. Some private companies and political actors were also sceptical about the economic viability of the project and about its added value for the community. In such cases, informational events about the risks and benefits of a heat transition, the transparency of the process, and insights into the specific implications of the project for households were organized in an effort to win over sceptical actors. In Rosenow, Bollewick, and Mauenheim, time-consuming face-to-face meetings were held with each household in order to inform citizens about the heat transition initiative as well as to build trust and strengthen personal ties. Bringing the different stakeholders of the local heat transition together in public meetings or in local councils to discuss benefits and problems in an atmosphere of trust contributed to new forms of self-organization and community-building.

As a result of the community-building activities from the beginning of the bioenergy initiative, the interviewees generally reported a collaborative and a mostly positive, long-standing relationship between the different stakeholders of the bioenergy villages. It is clear that many stakeholders support the heat transition and have developed a sense of local ownership. As one local decision-maker in Bollewick noted, "*We formed a community that stood together and pushed through against adversity. What you need is a certain group of people who are convinced of this [bioenergy project] and who stand together*" (Interview Bollewick). In Rosenow, the municipality and a regional heat supplier were frustrated by long bureaucratic approval processes that had slowed implementation, and they thus ambitiously founded a municipal company without waiting for permission from the relevant authorities. However, this was an exception. In most cases, horizontal forms of cooperation take place with private, public, and civil society actors. In the process, the different actors form a network that both intentionally and unintentionally contributes to increasing social acceptance and to participatory processes in new heat transition infrastructures and technologies.

In the planning and implementation phase, majority decision-making is the most common mode of interaction. In Mauenheim, regular meetings are organized with farmers, the mayor, project developers, and engineering companies. Bollewick also forms a consortium with the mayor, farmers, and project developers. These meet-

ings are set up in order to coordinate the process and to exchange viewpoints and information as well as to discuss the next steps and what has been learned. In some bioenergy villages, open construction sites are also set up during the implementation phase in order to allow people to ask questions, to learn about technical, financial, and organizational implications, and to actively participate in the project. Finally, inter-municipal exchange was also mentioned by interviewees as an important activity for planning and implementation. Visits to other bioenergy villages, renewable energy projects, and other municipalities are organized, and external actors are invited to share their experiences and ideas as well as to expand their networks of supporters of local heat transitions. In this regard, interviewees from Lampertsweiler also pointed to regular meetings with a biogas association. Cooperation and learning activities in local networks can thus be seen as key elements in bioenergy villages that enable quick adaptation to local problems and that motivate people who feel that they can change processes.

4.3 Entrepreneurs

In the local communities under investigation, certain actors were found to play an exceptional role in the creation and implementation of bioenergy villages. First and foremost, farmers were found to play an entrepreneurial role in these processes. As the following quote illustrates, interviewees described farmers as well-known, respected, and popular citizens who contribute significantly to the public acceptance and success of local bioenergy projects: "*Two farmers supported the bioenergy project. They were well connected. That was actually the decisive point. They were popular in the village, they were trusted, and that's why the people went along with it [i.e. the farmers' plans]*" (Interview Mauenheim).

In this case, two farmers used their reputation and resources to initiate local multi-stakeholder cooperation and to develop the innovative idea of a bioenergy village. The other bioenergy villages reported similar farmer involvement. Farmers often organized—or were important actors in—public events aimed at informing citizens about their projects. These farmers were personally committed to the idea of a bioenergy village because it allowed them to create value and produce energy from their biomass. Furthermore, the farmers identified and framed the bioenergy project as an opportunity to promote social and environmental well-being in the community to which they were personally attached. As a result, they were able to persuasively bring together the preferences of diverse local actors and to develop actor coalitions in order to create local change.

In most cases, the farmers were members of the local council (Rosenow, Mauenheim, Wolpertshausen-Hörlebach) or were even deputy mayors (Wolpertshausen-Hörlebach, Rosenow), and they were thus able to use their political knowledge to moderate and coordinate multi-stakeholder processes for realizing a heat transition despite criticism. In Lampertsweiler and Wolpertshausen-Hörlebach, farmers were willing to take a risk and invest not only in a biomass plant, but also in the operation of the heat grid. They allowed customers to contact them by phone or instant messenger in case of technical problems or questions. Such personal commitment, direct communication channels, and proximity to citizens were highlighted as advantages

of bioenergy villages because these elements were found to have contributed to broader public acceptance and trust.

All interviewees emphasized the importance of political support at the local level. In almost every case, political actors were supporters of bioenergy villages. As respected and trusted members of the community, these political actors' reputations had helped to increase citizens' acceptance of the projects and to convince these citizens to connect their houses to the local heat grid. Both informing and convincing people of the benefits of bioenergy initiative were found to be necessary because in almost all cases, connection to the heat grid was voluntary. Among the local political actors, mayors, in particular, showed entrepreneurial qualities. Indeed, they were key actors in most bioenergy villages (with Lampertsweiler being the only exception because the mayor opposed the idea of the bioenergy village due to conflicting economic interests). Mayors were found to act as advocates and to implement or even initiate the transformation of the local heating system. In some cases, they were found to have been committed to the energy transition for more than a decade. For example, in Wolpertshausen, the mayor has been in office for more than 30 years and has supported energy projects in the municipality since the 1990s.

In the interviews, the mayors mentioned public welfare goals (e.g. regional added value, energy independence, attractive living conditions) as well as ecological interests (especially climate protection) as their motivation. For example, the mayor of Rosenow was found to promote the vision of a carbon-free municipality with the hope of tax-related benefits (CO_2 tax) in order to compensate for low trade tax revenue. Despite their honorary office, mayors were found to invest time and effort into realizing and advancing their bioenergy villages. Therefore, their political support in the local council is important when it comes to realizing the heat transition: "*We pushed through a small biogas plant here against all odds back in the mid-90s. I think that was my biggest local council meeting with a few hundred listeners for and against [the plant]*" (Interview Wolpertshausen). Mayors were found to engage and cooperate with farmers and to have helped to convince local citizens to connect to the heat grid.

The former mayor of Bollewick stands out as a policy entrepreneur. He was the initiator of the bioenergy village. Equipped with institutional resources but lacking the technical means to implement his idea on his own, he built alliances with key actors (e.g. a project engineer, farmers, a regional heat supplier) and convinced members of the local council of his idea: "*The mayor was able to set the political course in the municipal council*" (Interview Bollewick). He was a co-founder of the consortium that steered the process, and together with the project engineer, he made time-consuming door-to-door visits in order to explain the opportunities and benefits of the bioenergy village. Furthermore, the mayor initiated regional cooperation by building a network of bioenergy villages with the aim of helping other municipalities become bioenergy villages. The mayor of Rosenow was also a member of this network and participated in various working groups. In order to promote the idea of the bioenergy village, he visited other energy projects and participated in a roadshow for sustainable development. In this context, Rosenow was selected as a model municipality and received coaching from a research institute.

Economic actors can also have entrepreneurial qualities, as can be seen in the case of Wolpertshausen, in which the founder and managing director of the company Ökoprojekte Gronbach built the local district heating. The same person was also the founder of an international company that builds biogas and photovoltaic plants. He has extensive resources concerning not only technical know-how, but also financial capacities and networks. Due to his widespread business relations, for example, due to his membership in the Biogas Association, he is well connected beyond the local level. This man is well-known and accepted by the local community, and as a long-time member of the local council, he has access to institutional resources. He used these resources to promote innovative ideas for the heat transition in the local council as early as during the 1990s. In this way, he was able to build a biogas plant in the 1990s in cooperation with local farmers, who supplied the substrate. This plant supplied the "Ökopark", which is a commercial and residential area that the man bought and developed in line with certain ecological standards and with the permission of the local council. The biogas plant was replaced by a wood chipping plant in 2009. Nevertheless, this man continues to develop the bioenergy village even today with innovative approaches and technologies (e.g. planning a new combined heat and power plant using biomethane).

Finally, the interviewees pointed to windows of opportunity that policy entrepreneurs use to promote their projects and to convince citizens of these projects' benefits, as illustrated in the following quotes: "*Energy prices also went up at the beginning of the 2010s, which supported our argument*" (Interview Mauenheim). "*At the time, people said [that] the mean oil price was always going up and down. And we said, 'Not for us'*" (Interview Mauenheim). In contrast, times of low fossil energy prices can be an obstacle to the implementation of bioenergy villages. In Rosenow, citizens tried to get out of their heating contracts, and the regional heat supplier—which is involved not only in Rosenow and Bollewick, but also in other municipalities and bioenergy villages—was unable to sell waste heat.

Concerning energy prices, the Russian war in Ukraine that began in February 2022 has also had an impact on bioenergy villages. Before the war, Germany was heavily dependent on Russian gas imports for its private and industrial heat supply. In particular, Mecklenburg-Vorpommern invested heavily in Russian gas projects through the North Stream I and North Stream II pipelines. Citizens benefited from relatively low fossil fuel prices for their heating, and the need for a transition to renewable heat only emerged as a problem in the public debate when cooperation with Russia was drastically reduced as a result of the country's attack on Ukraine. New questions arose about energy security in Germany, and fossil energy prices increased significantly in 2022. These developments were challenging for many households. Driven by fear and uncertainty about the national heat and energy supply, citizens became more interested in decentralized solutions that emphasize approaches of community ownership and self-sufficiency. Interviewees reported that as a result, citizens had become more interested in bioenergy and in being connected to the local heat grid. The stable and favourable heat price for bioenergy (i.e. 5–9 euro cents per kilowatt hour) was considered an attractive alternative to rising and uncertain prices for gas or other fossil fuels. Hence, the significant reduction in the German-Russian energy cooperation due to the Russian war in Ukraine seems to

have marked another window of opportunity for farmers and mayors to successfully argue in favour of bioenergy projects.

5 Discussion and conclusion

Our exploratory study aimed to provide a deeper understanding of the relationship between actors and institutions in bioenergy villages and to derive success factors in the implementation of these villages. By analysing primarily expert interviews with actors who are actively involved in the implementation of bioenergy villages, we were able to compare five typical cases in two different German federal states: Mecklenburg-Vorpommern and Baden-Württemberg. We revealed that the contribution of bioenergy villages to the German heat transition is not merely a question of technological feasibility, economic viability, or the effective reduction of CO_2 emissions (Jenssen et al. 2014). Indeed, we argued that this contribution is mainly about the intentional activities of resourceful actors, the interplay between local actors and institutions, and the situational context.

Despite the different actor constellations in Rosenow, Bollewick, Lampertsweiler, Wolpertshausen, and Mauenheim, a multidisciplinary network that includes farmers, private and municipal companies, political actors, and citizens was found in all bioenergy villages. Our study thus reinforces the observation made by Seyfang et al. (2013) that community energy requires the cooperation of different stakeholders with diverse objectives and that civil society is fundamental to the success of such energy. In line with the results of the study by Bock and Polach et al. (2015), we demonstrated that trustworthy local networks in which diverse stakeholders develop strong ties for cooperation and information exchange and accept new local infrastructures and technologies determine the success of bioenergy villages. This finding can also be linked to the findings of Walker et al. (2010), who pointed out the importance of trust between local people and groups in driving forward community renewable energy projects. Drawing on the work of different authors in the field (including Forman 2017; Hanke et al. 2021; Thomas et al. 2020; Wahlund and Palm 2022), these decentralized participatory multi-stakeholder processes that are in search of an affordable and environmentally friendly solution can be argued to contribute to the German heat transition by promoting energy justice, energy citizenship, and energy democracy. These processes can also foster learning processes and flexible adaptation to local issues and diverse interests, which are important prerequisites for effective change.

Most importantly, we demonstrated that the examined bioenergy villages are home to entrepreneurs who combine different societal roles, such as those of farmers, politicians, and local business owners. Our analysis indicates that these local entrepreneurs are characterized not only by their preference for a local heat transition, but also by the fact that they mobilize financial, technical, political, and social resources, that they are linked to diverse networks, that they are well-known, and that they enjoy positive reputations. We contributed to the debate on local entrepreneurship by confirming that these entrepreneurs use their extensive resources to channel local concerns or conflicting interests and expectations, build coalitions

and trust, and address institutional challenges. The entrepreneurs are able to identify favourable conditions that foster the idea of a heat transition (Ackrill and Kay 2011). In addition to Eckersley (2018), we argue that local entrepreneurs are important not only for stimulating local processes, but also for implementing and diffusing these projects. Therefore, through their personal engagement, the bioenergy project can pave the way for a heat transition that is socially more profound and accepted than a mere technological fix would be (Capellán-Pérez et al. 2018; Vernay et al. 2023). Like Böcher (2016), we argue that these regional entrepreneurs both influence and are influenced by institutions – in our case, institutions in the heat sector.

Consistent with the findings of Roesler and Hassler (2019) and Wüste and Schmuck (2012), we also demonstrated that the contribution of bioenergy villages to the heat transition is determined at the local level through the interaction of actors, whereas federal, state, and local administrations define the structural environment of bioenergy villages. Accordingly, bioenergy-related policies and policy instruments can be catalysts for local heat transitions. However, this process depends on political support and on the ability of local stakeholders to successfully apply for funding. In line with other studies that have highlighted the importance of an overarching incentive structure and national funding for local climate action (Zeigermann et al. 2023), we found that all analysed bioenergy villages had benefited from the Renewable Energy Act. Surprisingly, however, our findings on state institutions remain inconclusive. More detailed analysis is thus needed in order to assess institutional implications. In considering the role of municipalities in multi-level heat transition processes, it can be argued that these municipalities take on local responsibility and contribute to a polycentric governance of the heat transition (Tosun and Rossello 2020). Accordingly, bioenergy villages can form a network structure in which local and transnational knowledge is used and learning processes are stimulated in order to solve collective problems such as heating (Ostrom 2010). As such, these villages can increase the flexibility and autonomy needed to address energy supply problems in Germany as well as climate-friendly innovation.

In general, actor-centred institutionalism was found to provide a useful framework for studying the interactions between local actors from bioenergy villages and (multi-level) institutions. In order to fully capture the role of policy entrepreneurs and to study interactions with the situational context, we combined this framework with analytical frameworks that deal with policy entrepreneurship, which allowed us to highlight the exceptional role of farmers, mayors, and economic actors. We additionally showed that the Russian war in Ukraine marked an important event for all bioenergy villages due to rising energy prices, new demands for energy autonomy, and the growing public debate on heating. In this context, bioenergy villages gained new attention as pioneers of the heat transition. In order to focus more closely on the role that such dynamic situations play in local transitions, further analysis that operationalizes the political process-inherent dynamics approach (PIDA) (Böcher and Töller 2012) as a conceptual framework may prove useful.

In conclusion, dynamic interactions in bioenergy villages were found to make important contributions to the heat transition. In the case of local multi-stakeholder interactions, these contributions can be defined as the increasing acceptance and support of citizens for energy transitions (cf. energy citizenship; Wahlund and Palm

2022), collaborative self-governance through participatory learning processes, and the mobilization of capital in order to foster regional added value. We identified characteristics of the local entrepreneurs who serve as the main drivers of bioenergy villages. In the case of interactions with institutions, the contribution that bioenergy villages can make to polycentric heat governance was highlighted. The situational context can draw attention to the pioneering role that bioenergy villages play in self-sufficient, democratic, affordable, economically viable, and climate-friendly heating, which can inspire learning and greater local action.

Our study has several limitations, especially regarding its small sample size, which makes it difficult to generalize our findings. Nevertheless, our study provides a good basis for more deeply exploring the factors that determine the success of bioenergy villages. Against this background, several considerations emerge from our analysis that could help further research. First, further analysis of bioenergy villages across all federal states in Germany might reveal additional contributions that these villages can make to the heat transition and could additionally provide more nuanced insights into identified actor-related, institutional, and situational factors. Moreover, such further analysis could also help to determine whether all or only some of these factors are critical when it comes to implementing bioenergy villages. Second, a comparative analysis that focuses on regional institutional settings and policy instruments could provide important insights into the structures of polycentric heat governance. Finally, in light of the increasingly controversial debate on the heat transition in Germany and the polarization of the climate discourse, conflicts in local heat transitions—and the resolution of these conflicts in bioenergy villages—represent an important field of research that requires further attention.

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