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The influence of visions on cooperation among interest organizations in fragmented socio-technical systems

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Abstract

The paper shows that visions of the future can be used as a predictor of cooperation and division between actors in their efforts to shape the institutional environment, specifically policy in socio-technical systems. Accordingly, the paper suggests a new method to analyze visions: a virtual solution space in which visions can be grouped according to their similarity. The similarity of visions is calculated based on cluster analysis. Empirically, the paper focuses on the networks between industry associations in the heating transition in the German building sector. It shows that actors whose visions of future socio-technical system developments overlap are more likely to cooperate with each other. It also suggests that the fragmentation of the residential heating system in Germany is reflected in a fragmented actor network. Furthermore, the authors show that shared technological interests can outweigh similar visions. These fragmented technological interests hinder meaningful cooperation. This is potentially one reason why a powerful low-carbon heating coalition in Germany that could facilitate an accelerated deployment of low-carbon heat systems by driving policy change has not emerged to date. The paper contributes to a better understanding of how niche actors in sustainability transitions use their agency and specifically strategize to bring about institutional change. In this respect, the authors discuss how differing levels of system-fragmentation influence transition dynamics in general and institutional change dynamics in particular.

KEYWORDS

agency in transitions, building sector, cooperation, Germany, sustainability transitions, visions of the future

1 | INTRODUCTION

The pace of sustainability transitions (Sovacool, 2016) is crucial for achieving the UN's Sustainable Development Goals by 2050 but it is often hindered by unsupportive institutional environments. Institutional settings result from co-evolutionary processes (Unruh, 2000), and actors must engage in institutional work (Lawrence et al., 2011) in order to initiate change. Institutional change and socio-technical transitions (Geels et al., 2016; Hekkert et al., 2007; Rao et al., 2000; Raven et al., 2015; Smith & Raven, 2012; Van de Ven, 1993; Wijen & Ansari, 2016) are typically collective activities and do not originate from individuals. While uncoordinated activities can contribute for limited institutional work (Lawrence et al., 2011), actors can strategically coordinate collective action, such as "running in packs" (Van de Ven, 1999), to create favorable institutional conditions for novel technology diffusion.

Sustainability transitions literature to date has focused on collective action for institutional change among entrepreneurs with shared technological interests (Musiolik & Markard, 2011; Planko et al., 2016). However, different niche actors may struggle to cooperate due to varying perspectives on institutional changes (Geels, 2004; Sabatier, 1988; Smith & Raven, 2012). This paper explores determinants of cooperation among actors supporting different niche solutions, and focuses on visions as a key predictor (Bakker & Budde, 2012; Borup et al., 2006; Konrad et al., 2012). We hypothesize that actors with similar visions are more likely to coordinate actions and engage in institutional work than actors with dissimilar visions.

The aim of this paper is to contribute to the understanding of determinants of cooperation among actors from different niches and the emergence of strong coalitions in socio-technical transitions. Such knowledge may clarify reasons for differences in the pace of transition processes.

Focusing on the German residential heating sector (Wesche et al., 2019), we examine the impact of visions and cooperation on institutional change in sustainability transitions. The slow pace of transition in this sector might have resulted from a lack of policy schemes, problematic institutional alignment, and fragmented cooperation between niche actors (co2online, 2019; Dewald & Truffer, 2011). We explore how cooperation plays out in context-dependent and fragmented systems such as the German residential heating sector.

We aim to answer the following research questions:

1. How do similarities and dissimilarities in visions regarding desired end states of sustainability transitions determine cooperation between actors supporting different emerging socio-technical configurations?
2. What are the implications of the level of fragmentation in a socio-technical system for cooperation networks?

In addition to these two research questions, in Section 2 we develop the hypothesis that actors who share similar visions of the future are more inclined to cooperate when it comes to taking action toward policy change.

This study examines cooperation among 16 German interest organizations representing low-carbon energy technology using a virtual solution space, hierarchical clustering methods, and dendrogram results. We measured the fit between niche actors' visions and their cooperation on institutional change activities (Cheon & Urpelainen, 2013; Dewald & Truffer, 2011; Foljanty-Jost, 2005; Juerges & Newig, 2015; Otjes & Rasmussen, 2016). In focusing on industry associations representing specific technological fields, this study is the first to explore cooperation behavior among diverse technological configurations in a fragmented socio-technical system within transition studies (Geels, 2004).

This paper is aimed at contributing to a better theoretical understanding of the cooperation-related dynamics in fragmented socio-technical systems. Empirically, it offers a in detail account of cooperation-related behavior of industry representatives in the German residential heating sector. Methodologically, the paper introduces a new way to analyze cooperative data in transitions settings that may merit its use in studies that analyze other actor groups or investigate other socio-technical systems.

2 | THEORY: COOPERATION, VISIONS, AND COALITION-BUILDING IN SUSTAINABILITY TRANSITIONS

2.1 | The role of cooperation and coalitions in facilitating institutional and policy change

Sustainability transitions involve significant changes in socio-technical systems in order to provide societal functions more sustainably (Markard et al., 2012). Novel configurations emerge in niches and may be supported by either niche or regime actors (Berggren et al., 2015; Geels, 2004). Transitions require phasing out anachronistic configurations (Kivimaa & Kern, 2016; Turnheim & Geels, 2012), developing and deploying novel configurations, and amending existing institutional structures to support them (Fuenfschilling & Truffer, 2014).

Although the sustainability transitions literature, which includes works by Geels (2004), Loorbach (2010), and Hekkert et al. (2007), has made significant contributions, some critiques have address its limitations, such as its insufficient conceptualization of politics and power (Patterson et al., 2017; Smith et al., 2010), narrow focus on technological innovation (Temper et al., 2018), and overemphasis on bottom-up disruption pathways (Smith et al., 2005). Despite these critiques, we use concepts such as socio-technical niches and regimes to guide our theoretical inquiry.

In this paper, we focus on institutions as key elements of socio-technical systems (Andrews-Speed, 2016), acknowledging that socio-technical systems comprise various elements such as markets, technology, culture, and policy (Geels & Schot, 2007, p. 409). We concentrate on national-level policy, while recognizing that governance occurs at multiple levels (e.g., Smedby, 2019) and across national and subnational geographical borders (e.g., Jager, 2016; Stead, 2014). For socio-technical change to occur current policies, independent of the level, need to be de-aligned to destabilize unsustainable configurations and foster novelty (Geels & Schot, 2007).

We adopt Crawford and Ostrom's definition of institutions as "enduring regularities of human action in situations structured by rules, norms, and shared strategies" (Crawford & Ostrom, 1995, p. 582), and differentiate them into regulative, normative, and cognitive structures (Fuenfschilling & Truffer, 2016, p. 298; Scott, 1995).

Both innovation science literature (Garud & Karnøe, 2003; Hargrave & Van de Ven, 2006; Rao, 2004; Van de Ven, 2005) and socio-technical transitions literature (Hekkert et al., 2007; Musiolik & Markard, 2011; Planko et al., 2016) emphasize that institutional change is driven by coordinated collective action, such as coalitions advocating for change. This aligns with the idea that actors "run in packs" (Van de Ven, 2005, p. 365) and create new paths through distributed efforts (Garud & Karnøe, 2003, p. 296), with coalitions catalyzing legitimacy and inciting "creative destruction" (Hekkert et al., 2007, p. 425).

Similarly, in the literature on socio-technical transitions, system-level change is seen as "enacted through the cooperation and steering of many actors and resources" (Smith et al., 2005, p. 1492), and the findings of research on how actors engage in changing institutional environments of sociotechnical systems are presented (e.g., Berggren et al., 2015; Fuenfschilling & Binz, 2018; Fuenfschilling & Truffer, 2016; Hess, 2016; Jacobsson & Bergek, 2004; Jolly & Raven, 2015; Rennkamp et al., 2017; Smink et al., 2015; Smith & Raven, 2012; Ulmanen et al., 2009). For example, Ulmanen et al. (2009, p. 1415) suggest that "the creation of a protected space [for a new socio-technical configuration] involve[s] dedicated lobbying by a variety of actors joined in advocacy coalitions." However, such coalitions not only need to create a protected space by "institutionalizing niche practices" but also need to become sufficiently powerful to be able to establish them as real alternatives to "routines in socio-technical regimes" (Smith & Raven, 2012, p. 1030). With regard to the composition of coalitions in transitions, Jacobsson and Bergek (2004, p. 822) make the following claim with regard to coalitions:

> [they] may include many types of organizations and actors, such as universities, private and non-commercial associations, media, politicians at different levels and elements of the state bureaucracy. However, individual firms and related industry associations play an especially important role in the competition over institutions.

Both innovation and transitions scholars argue that coordinated action and coalition building are vital for institutional change, with meaningful cooperation as a key prerequisite (Musiolik et al., 2020; Normann, 2017). However, there is a need for a better understanding of what determines cooperation in sustainability transitions, particularly in highly fragmented systems. Transition pace varies due to fragmentation levels (Sovacool, 2016; Wesche et al., 2019). Wesche et al. (2019) suggest that less fragmented systems transition faster, while more fragmented ones take longer due to intricate de-alignment and realignment processes. This study explores whether high fragmentation levels impact actors' cooperation in adjusting institutional environments, focusing on the same system studied by Wesche et al. (2019).

2.2 | Overlapping visions as a proxy for cooperation

Our argument builds on sustainability transitions literature that shows how expectations coordinate collective action, and shared visions of the future predict coordinated activity and coalition formation (Ansel & Gash, 2007; Sabatier, 1988; Wijen & Ansari, 2016). However, there is a need to understand of how visions and expectations specifically influence cooperation in sustainability transitions.

Research on expectations and visions in sustainability transitions has been grounded in the concept of "sociology of expectation" used in science and technology studies (STS) (Borup et al., 2006; Brown & Michael, 2003). Technological expectations are "real-time representations of future technological situations and capabilities" (Borup et al., 2006, p. 286). They provide a guiding structure in emerging fields, and they structure innovative actors' activities (van Lente et al., 2013, p. 1616). As expectations become collectively held visions, they turn into an "accepted part of the social repertoire" (Kriechbaum et al., 2018, p. 77). Visions in the process of becoming part of the social repertoire "cannot be ignored even by those that do not share its ideas" (van Rijnsoever et al., 2014, p. 639). Hence visions of the future can become obdurate forces that shaping emerging technological fields (van Lente et al., 2013, p. 1616).

Conceptualizations of visions have been echoed in sustainability transitions research, thus acknowledging their importance in destabilizing outdated socio-technical regimes and consolidating novel configurations (Geels & Schot, 2007; Jørgensen, 2012; Kemp et al., 1998; Loorbach, 2010; Späth & Rohracher, 2010). Berkhout (2006, p. 304) suggests that future visions are crucial in regime transformation, as regimes lacking adaptive capacity and connected to compelling visions will not be sustainable. Empirically, visions have been used to assess transitions, such as a bio-based economy in Norway (Hansen & Bjørkhaug, 2017), and to understand intermediaries in low-energy housing in the UK, heat pump diffusion in Finland, and the Dutch automobility sector (Kivimaa, Hyysalo, et al., 2019).

Visions fulfill a key function in the envisioning of desirable futures and thus motivate socio-technical change, even though "end-points (of transitions) are highly contested or only partially understood" (Smith et al., 2005, p. 1506). For visions to be powerful and to stimulate change, they need to be aligned so that the activities of groups that support them can be coordinated (Geels & Schot, 2007, p. 402). Such alignment of visions can be facilitated by "intermediaries [who] act as brokers between multiple priorities, interests and knowledge pools" (Kivimaa, Boon, et al., 2019, p. 1067). The guiding nature of visions in transition processes is also picked up in transitions management and in the technological innovation systems literature. From the transition management perspective, "the term "guiding vision" depicts an instrument in an agenda building process with regard to long-term policy goals and transformation strategies" (Späth & Rohracher, 2010, p. 451). According to Rotmans et al. (2001, p. 23), visions "function as a framework for formulating short-term objectives and evaluating existing policy." They suggest that for visions to be successful and drive socio-technical change, they "must be appealing and imaginative and be supported by a broad range of actors" (Rotmans et al., 2001, p. 23). In the technological innovation system literature, visions are a key component in the guidance of the search function, which when fulfilled helps to channel scarce resources toward socio-technical solutions that help to realize previously envisioned future (Bergek et al., 2008; Hekkert et al., 2007).

With regard to the characteristics that make visions influential, Smith et al. (2005) suggest that a vision should ideally be backed and endorsed by influential and credible supporters. Furthermore, it should contain a certain degree of "interpretative flexibility," and at best it should feature a general fit with the "cultural and political context, in which it is propounded" (Smith et al., 2005, p. 1507).

Considering the role of visions in transition studies, we hypothesize that niche actors are more likely to cooperate with those sharing similar transition visions than with actors who have dissimilar visions. We also hypothesize that fragmented socio-technical systems will exhibit fragmented cooperation, thus hindering the emergence of dense cooperation networks needed for strong coalitions to drive institutional change.

2.3 | Collective action and characteristics of coalitions in sustainability transitions

Sustainability transitions are complex and encompass a large variety of actors, some of whom are interested in reinforcing current practices (regime actors) and others who want to challenge them and who propose novelty and change (often niche actors). To date, institutional work, collective action, and related concepts have generally been analyzed in single technology cases (Jolly & Raven, 2015; Konrad et al., 2012; Musiolik & Markard, 2011; Rosenbloom et al., 2016). Even in those cases, meaningful cooperation and coordination for institutional change has been challenging. However, organizing meaningful collective action in multi-innovation cases is likely to be even more challenging. Due to the variety of niche actors, there may also be a variety of visions of the future and proposals for socio-technical solutions to realize them. In such complex settings, it is unlikely that large numbers of actors would converge by default toward a single, more sustainable vision of the future. Furthermore, actors' visions of the future in multi-innovation cases are likely to be even more fragmented than in single innovation cases, due to the divergent set of solutions and visions proposed by regime challengers. Under such conditions, it is unlikely that a clear-cut and cohesive coalition would emerge by default. Rather, the emergence of powerful and coherent coalitions in sustainability transitions should be understood as the result of substantial efforts on the part of potential coalition members. Despite fragmentation and variety, this does not mean that the emergence of large and powerful coalitions is not possible in multi-technology cases. Several empirical studies, such as those conducted on the German low-carbon electricity transition, have shown that even in multi-innovation cases a large and powerful coalition can emerge eventually (Dewald & Truffer, 2011, 2012; Jacobsson & Lauber, 2006).

2.4 | Interaction of technical solutions

To assess similarities and dissimilarities in visions, we introduce the notion of a solution space. A solution space is a virtual space that embodies a set of articulated visions. Essentially, a solution space can be imagined as a multidimensional cloud, in which different areas display distinguishable and specific types of visions of the future. Each of the visions virtually displayed in a solution space is constructed from dimensions that differ from vision to vision. Depending on the complexity of a socio-technical system, the number of dimensions may vary. For example, for the mobility transition, relevant dimensions may be related to public versus private transport or to the type of fuel and infrastructure used for mobility. Although actors might agree on some dimensions, they will be in competition if they diverge on other relevant dimensions of the solution space. For example, niche actors who support electric mobility will be in symbiosis with those who support cars running on biofuels, since both groups of actors envision future mobility based on individual mobility. Conversely, e-car advocates will be in competition with biofuel supporters when it comes to the fuel dimension. The complexity of such a solutions space is determined by the product of the dimensions that describe each vision or that make each vision distinguishable from the other visions.

When visions overlap more dimensions, they will be more similar than when they overlap fewer dimensions. Hence, they may partly overlap or may differ entirely from all dimensions. The more dimensions of each of the distinguishable visions are constructed, the more complex a solutions space will become. Solution spaces can, but do not necessarily, relate to sustainability-related visions of the future, but they can also be constructed around any other set of visions. We suggest that actors who align on many dimensions are in close proximity to one another in the solution space. We anticipate that if actors are close together in the solution space, they will be inclined to coordinate. Consequently, we also expect that actors who do not share many relevant dimensions will be more distant from each other in the solution space and also less inclined to cooperate.

Our main expectation is that the probability of cooperation between actors will depend on their alignment concerning dimensions, whether technical or otherwise, in the solution space. When many actors share the same relevant dimensions, they are likely to cooperate and jointly press for institutional change. If this expectation is supported, it will in turn support reasons to believe that visions can be used to predict cooperation and coalition building in socio-technical systems.

2.5 | Technological dimensions as a predictor of cooperation

To test whether visions can be used as predictors of cooperation and coalition-building, visions need to be made measurable. To do so, we suggest that relevant dimensions of how visions differ need to be determined. Since visions are likely to be closely linked to the context of each socio-technical system, we suggest that one way to determine relevant dimensions could be through in-depth interviews. Once relevant dimensions have been determined, a solution space could be constructed, and the visions to be analyzed could be collected and

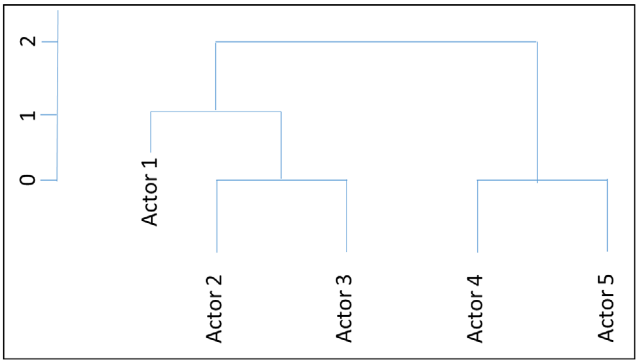

FIGURE 1 Explanatory dendrogram.

classified according to those dimensions and the solution space. To test whether visions can function as predictors of coordinated behavior, the distance between them needs to be determined. This can be done by conducting a hierarchical cluster analysis. In a hierarchical cluster analysis, structural similarities and dissimilarities among actors can be employed to analyze and visualize the distance between envisioned futures.

The calculation of hierarchical clusters based on structural similarities and dissimilarities is a well-known process in the analysis of networks (Wassermann & Faust, 1994), and is frequently applied in the study of policy networks and advocacy coalitions (e.g., Leifeld, 2013). The results of hierarchical cluster analyses can be displayed in the form of a dendrogram, as shown Figure 1. Dendrograms are read from the bottom upwards. When interpreting a dendrogram, the agglomeration height at which any two or more actors are connected is important. The agglomeration height depicts the degree of similarity/dissimilarity between two groups. In our case, the agglomeration height shows the degree of similarity between the futures envisioned by actors. Actors who are connected at the highest height have a dissimilarity score of 0, meaning that they agree on all dimensions and that the futures they envision are congruent. In other words, the less the difference in height, the closer the visions, and conversely, the greater the difference in height, the more the visions diverge. For example, in Figure 1, Actors 2 and 3 are structurally equivalent because they have a dissimilarity score of 0. This means that they align on all analyzed dimensions. Similarly, Actors 4 and 5 share all dimensions and are thus structurally equivalent. The higher the level that connects the actors, the more dissimilar they are concerning the envisioned futures. For example, Actor 1 does not share all dimensions with Actors 2 and 3. Actor 1 is only connected with Actors 2 and 3 at the dissimilarity level 1. However, at a dissimilarity level > 1, Actors 1, 2, and 3 can be denoted as a cluster, and Actors 4 and 5 form a second cluster because the futures that they envision are closer to each other than to the respective futures of the other cluster. Dendrograms are helpful for revealing similarities among actors. However, as they show clusters, single dimensions that are shared between actors located in different clusters may be omitted and remain invisible.

TABLE 1 Overview of interviewees.

Interviewee number and industry association	Interviewee's position
#1 Pellets	Managing director
#2 Biodiesel	Policy advisor
#3 Biogas	Managing director
#4 Biomass	Managing director
#5 Geothermal heat	Managing director
#6 Solar power	Policy advisor
#7 Heat pumps	Policy advisor
#8 Umbrella group—insulation materials	Managing director
#9 Umbrella group—energy efficiency	Managing director
#10 Mineral wool	Managing director
#11 Extruded polystyrene foam	Managing director
#12 Polyurethane foam	Managing director
#13 Insulation installation systems	Managing director
#14 Natural gas	Managing director
#15 Combined heat and power	Managing director
#16 Large heating grids	Vice president, responsible for policy

3 | METHODS

We conducted a visions and cooperation study of the German residential heating sector. Since this sector has substantial greenhouse gas emissions, the problem is how to change established institutions in ways that would significantly reduce such emissions. The sector is also characterized by high levels of fragmentation, for example in terms of actors and technological solutions (Wesche et al., 2019). We chose industry associations as focus actors because in transition contexts they "play an especially important role in the competition over institutions" (Jacobsson & Bergek, 2004, p. 822). We argue that it is sensible to use industry associations as focal groups for the following reasons: (1) they have a clear message and can therefore function as signposts for actors to gather and meet, (2) they have the funds to organize meetings of potential coalition members and therefore they are likely to act as hubs for coalition building, and (3) they are likely to be well connected in the heating sector and involved in political processes. Furthermore, because industry associations represent specific technologies, they allow for a good overview of where visions of the future overlap and where they differ. In our study, all 22 industry associations in the German domestic heating system were contacted, and 16 representatives of those associations were interviewed in autumn 2018 (Table 1).[1] We have treated these interviewees as representing the views of the respective organizations. They were identified based on desktop research and four preliminary interviews: two with German energy system researchers and two with representatives of industry associations.

Of the 16 associations, 7 promote renewable energy sources, 6 promote insulation materials, and 3 promote either a more efficient use of fossil fuels or fuel switching options (Table 1).

The interviews consisted of two parts. The first part was semi-structured and included questions about how the interviewees comprehended and envisioned the residential heating transition in Germany. The questions are listed in the Appendix A. To the best of our knowledge, sets of dimensions that constitute visions do not exist in the literature and therefore can be used in a general way. Furthermore, due to the plethora of visions for system development, we argue that relevant dimensions need to be explored and specified in the context of each system in question. For this reason, we adopted a mixed methods approach in our research. Although this paper is theory-driven, we use a grounded inductive approach in the analysis section (Section 4) to determine relevant vision dimensions.

In the second part of the interviews, each of the 16 interviewees was given a list of all other industry associations in the domestic heating system.[2] For each of the listed industry associations, the interviewee was asked (1) whether the organization was unknown or (2) known, (3) whether there was interaction, and (4) whether there was cooperation (four levels). The scale is disjunctive while ascending, which means that the higher level includes the lower level. For example, if the representative of an organization stated that their organization interacted with another (level 3), it could be assumed that the two organizations also knew each other (level 2). Cooperation was defined as at least one joint activity in the preceding 2 years, such as a press release or a press conference. Interaction was defined as at least one jointly attended meeting in the preceding 2 years.

A two-step approach was used to test whether technology characteristics that shape visions of the future could predict cooperation among industry associations and therefore provide indications of cooperation behavior. The two-step approach comprised conducting semi-structured interviews and plotting the cooperation behavior of the interviewees.

In the first step, by choosing a semi-structured interview approach we were able to map the futures envisioned by principal actors in the German residential heating sector. We mapped those futures by transcribing and inductively labeling the interviews MAXQDA (software program designed for computer-assisted qualitative and mixed methods data). Thereafter, to achieve intercoder reliability, the interviews were inductively coded independently by the first author and by a research assistant at Fraunhofer ISI in Germany. Differences between their codes were reviewed, analyzed, and mutually resolved. Based on that process, we deduced relevant technology-related dimensions[3] that created the solution space for a low-carbon heating system in Germany. The data were used to compile a dendrogram, which was generated in “R” (statistical computing and graphic generation software). Based on the dendrogram, expectations were formulated concerning the cooperation behavior of the industry associations.

In the second step, we plotted the cooperation behavior of the interviewees to discover whether our outlined expectations had materialized. We collected cooperation network data to plot the cooperation behavior of the residential heating-related industry associations. Even though data for all four levels were collected, we only plotted cooperation data, since either interaction between actors or the sole knowledge of another actor was unlikely to foster institutional change. Jointly attended meetings did not count as cooperation, since industry association representatives often attended the same gatherings, but did so in order to issue political statements and not necessarily to organize collective action. The software visone (version 2.17) (Brandes & Wagner, 2004) was used to calculate and visualize network data.

4 | RESULTS: COOPERATION RELATING TO HEATING SOLUTIONS IN THE GERMAN BUILDING SECTOR

In this section we present and analyze our empirical data. First, we introduce the interviewees' visions of how the heating transition could evolve. Thereafter, we describe how, based on those visions, we derived seven technical dimensions that established the solution space for visions of the German domestic heating transition. The dimensions were used to perform a hierarchical cluster analysis in order to predict the cooperation behavior of the analyzed industry associations. In turn, the predictions were compared with the collected social network data on the cooperation of the analyzed industry associations.

4.1 | Visions of the German heating transition

The interview data suggest that the interviewees' visions of how Germany's domestic heating sector should change differed substantially. Some actors envisioned the heating transition as driven mainly by the diffusion of renewable-based technologies and the reduction of heat demand due to insulation. For instance, the managing director of the geothermal industry association stated:

> The heating transition for me is a complete change to the energy supply in the built environment. This includes the use of all now known and applicable technologies. So, it's not about geothermal only, but it is really about a complete rethinking of how buildings are supplied with renewable heat and that they are well insulated. (Interviewee #5)[4]

Other representatives envisioned the transition as based mainly on the efficient use of fossil fuels, with less attention paid to renewables or the use of insulation materials. For instance, the managing director of the natural gas industry association outlined the following approach to the domestic heating transition:

TABLE 2 Vision dimensions of industry groups in Germany's domestic heating system and related quotes.

Technical dimensions	Related quote
Technical dimensions related to emissions reductions	
1. Reduce CO_2 emissions by insulating buildings to lower their energy demand	"[F]or us, it is always efficiency first. We say the building must first be insulated to keep the heat inside. No matter where I get the heat from at the end. From the sun or anything else." (Interviewee #13)
2. Reduce CO_2 emissions by installing renewable heating technologies	"For me, the heating transition means the gradual conversion of the heating supply to renewable energies." (Interviewee #5)
3. Reduce CO_2 emissions by supplying buildings with technologies that are not yet available and that will run on renewable fuels that are not yet available	"If I then look into the future, after 2030, technologies such as power-to-gas or power-to-liquid will also be suitable for the mass market. This means that we will be able to offer competitive synthetic methane or synthetic liquid fuels produced from renewable electricity." (Interviewee #15)
4. Reduce CO_2 emissions by replacing the current fossil-based heating infrastructures with more efficient fossil-based heating infrastructures	"We have a built-in CO_2 advantage with gas. Switching from oil to gas saves 20, 30, 40 per cent CO_2. This perspective on fuel switching drives us forward. Yes, of course CO_2 is produced when gas is burned, but it is significantly less than if you burn oil or coal. Of course, we want to explore this advantage very clearly. It will certainly also help us to make good progress towards [meeting] our climate targets." (Interviewee #14)
Technical dimensions related to the scope of infrastructure	
5. Heating supply takes place at the level of individual buildings.	"Pellets are highly efficient. They have super CO_2 saving factors and they are cheap. […] Also, when you implement them in single-family homes, as we want to, then you can save ten tons of CO_2 per building." (Interviewee #1)
6. Heating supply is based on gas-based energy sources and requires gas networks.	"So the energy system of the future will be renewable plus gas, in all its facets, and the gas must, of course, also become green." (Interviewee #14)
7. Heating supply is based on heating networks.	"The overall trend, in my opinion, is these heating grids 4.0, where different technologies can feed in at different temperature levels, including geothermal energy." (Interviewee #5)

> Yes, of course, CO_2 is produced when gas is burned, but substantially less is emitted compared with burning heating oil or coal. […] Using more gas will certainly carry us a good distance towards the climate targets, especially because the fuel switch to gas is usually also the most cost-effective route. Insulation is always more expensive, and the introduction of renewable energy is even more expensive. It is important to reach a low-carbon system. However, we should always start with the low-hanging fruits. (Interviewee #14)

4.2 | Translating visions into technical dimensions

We identified seven technical dimensions in the data that could be used to differentiate the interviewees' visions. The dimensions created the solution space for how the heating transition could evolve. Four of the dimensions are directly related to how CO_2 emissions and can be summarized as follows:

1. Reduce CO_2 emissions by insulating buildings to lower their energy demand

TABLE 3 Technical dimensions and actors in Germany's domestic heating system.

	Dimensions related to emission reduction technologies				Dimensions related to the scope of infrastructure		
	Dimension 1 Insultating buildings to lower their energy demand	Dimension 2 Installing renewables heat technologies	Dimension 3 Installation of building technologies that run on renewable energies but are not available yet	Dimension 4 Upgrading outdated fossil heating boilers to newer, high-efficiency models	Dimension 5 Heat is supplied to individual buildings on a decentralized basis	Dimension 6 Heat supply is based on gaseous energy sources and requires gas networks	Dimension 7 Heat supply is based on heat networks
Pellets	0	1	0	0	1	0	0
Biodiesel	0	1	0	0	1	0	0
Biogas	0	1	0	0	0	1	1
Biomass	0	1	0	0	1	1	1
Geothermal	1	1	0	0	1	0	1
Solar	1	1	0	0	1	1	1
Heat pumps	1	1	0	0	1	0	0
Umbrella—building envelope	1	0	0	0	0	0	0
Umbrella—energy efficiency	1	0	0	1	0	0	0
Mineral wool	1	0	0	0	0	0	0
Extruded polystyrene foam	1	0	0	0	0	0	0
Polyurethane foam	1	0	0	0	0	0	0
Insulation installations systems	1	0	0	0	0	0	0
Large heat grids	0	0	1	1	0	0	1
Natural gas	0	0	1	1	1	1	0
Natural gas cogeneration	0	0	1	1	1	1	1

2. Reduce CO_2 emissions by installing renewable heating technologies
3. Reduce CO_2 emissions by supplying buildings with technologies that are not yet available and that will run on renewable fuels that are not yet available
4. Reduce CO_2 emissions by replacing the current fossil-based heating infrastructures with more efficient fossil-based heating infrastructures.

The remaining three dimensions do not relate directly to the reduction of CO_2 emissions, but to the scope of the infrastructure:

5. Heating supply takes place at the level of individual buildings.
6. Heating supply is based on gas-based energy sources and requires gas networks.
7. Heating supply is based on heating networks.

Quotes from the interviewees concerning the seven dimensions are listed in Table 2. Data from each of the 16 interviews were coded and analyzed with regard to the dimensions, and the results are presented in Table 3. An actor scored "1" on a dimension if that dimension appeared in his/her vision and "0" otherwise.

4.3 | Hierarchical clustering of technical dimensions

To discover which actors are aligned along the seven technical dimensions and are therefore in close proximity in the solution space, we performed a hierarchical cluster analysis based on the data presented in Table 3. The results are illustrated in the dendrogram in Figure 2, in which actors whose visions were very similar are shown as members of clusters and subclusters. If the hypothesis developed in the theory section (Section 2) holds (i.e., that actors who share similar visions of the future are inclined to cooperate), the clusters displayed in the dendrogram should predict cooperation patterns.

The dendrogram (Figure 2) shows that the industry associations are split into two clusters at a score of 2. Cluster A encompasses all 13 industry associations (i.e., represented by the interviewees) that envisioned the heating transition as either driven by lowering the energy demand of buildings (dimension 1) or driven by using the available renewable energy technologies (dimension 2). Cluster B encompasses three actors (red and orange), who envisioned a more efficient use of fossil fuels (dimension 4), and a substantial use of heating

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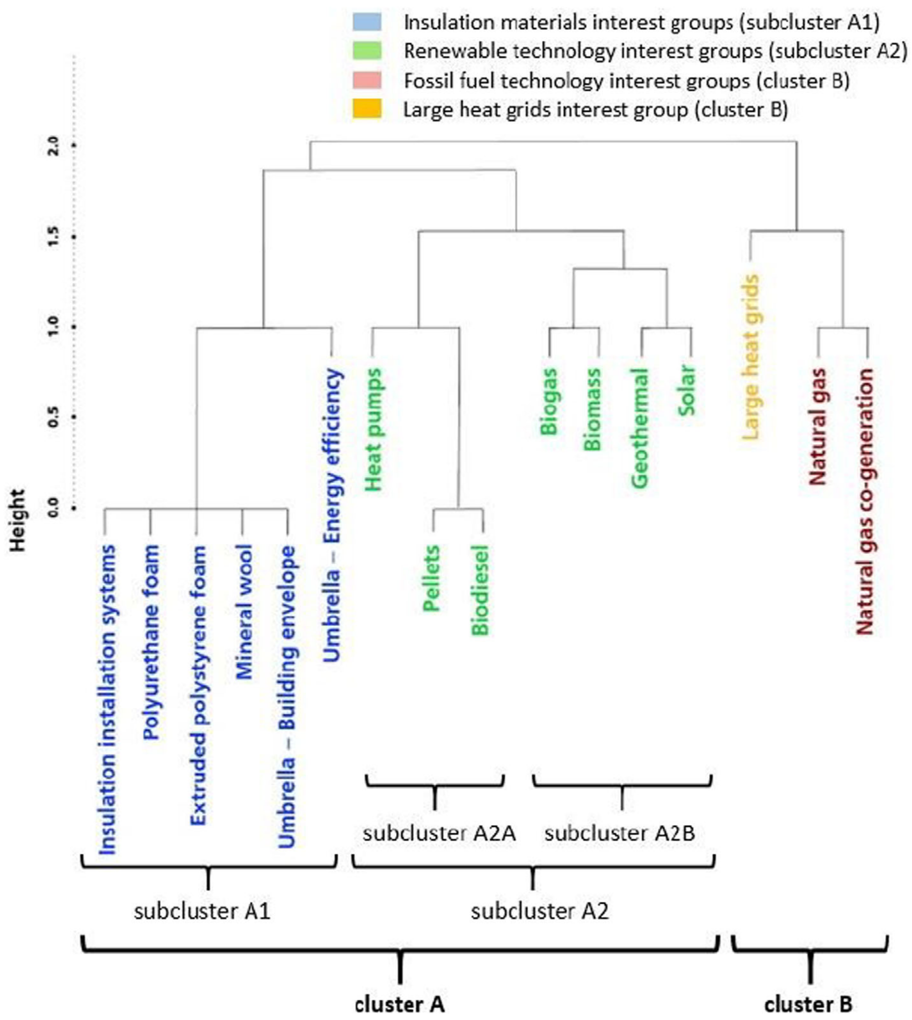

FIGURE 2 Dendrogram based on hierarchical clustering of technology industry associations' vision dimensions.

networks, as well as gas networks (dimensions 6 and 7). All three actors in cluster B also thought that demand for heat would eventually be met by renewable energy sources. However, they believed this would only happen in the long term and mainly using fuels that are not yet widely available (dimension 3).

Since cluster B encompasses only three industry associations and cluster A encompasses 13 industry associations, we analyze cluster A in more detail, as follows. At a height score of about 1.7, cluster A is divided into two subclusters.

Subcluster A1 encompasses all actors who envisioned the heating transition as mainly driven by reducing heat demand (blue). All six actors in this subcluster promoted insulation materials. In the interviews, five of the six representatives focused solely on the dimension of reducing heat demand (dimension 1). Since those five did not mention any of the other six dimensions, the presented associations are all structurally equivalent and therefore feature a dissimilarity score of 0. The umbrella group for energy efficiency also envisioned the heating transition as based on reducing the heat demand of buildings by diffusing insulation materials. However, as the group saw efficiency as a general goal, it also regarded the use of efficient fossil fuel infrastructure as a viable option to reduce carbon emissions (dimension 4). For this reason, it was not structurally equivalent to the other five industry associations that promoted insulation materials.

Subcluster A2 encompasses all industry associations that envisioned the heating transition as mainly driven by renewable fuels (dimension 2, green). It encompasses all actors who promoted available renewable heating technologies. Even though the interviewed representatives all agreed on the general trajectory, the dendrogram shows that their visions were more fragmented than the visions of the actors in subcluster A1. Therefore, at a score of 1.5, cluster A2 is again divided into two subclusters. Subcluster A2A encompasses industry associations that envisioned the heating transition as driven by individual building's heating systems (dimension 5). These are industry associations that promote the use of heat pumps, pellets, and biodiesel. By contrast, subcluster A2B encompasses actors whose visions of the heating transition included gas infrastructure and/or heating networks (respectively dimension 6 and dimension 7). These are the biogas industry association, the biomass industry association, the geothermal industry association, and the solar industry association.

From a comparison of the structure of subclusters A1 and A2, it is apparent that cluster A1 is substantially less fragmented than cluster A2. For example, in cluster A1, five of the six industry associations are

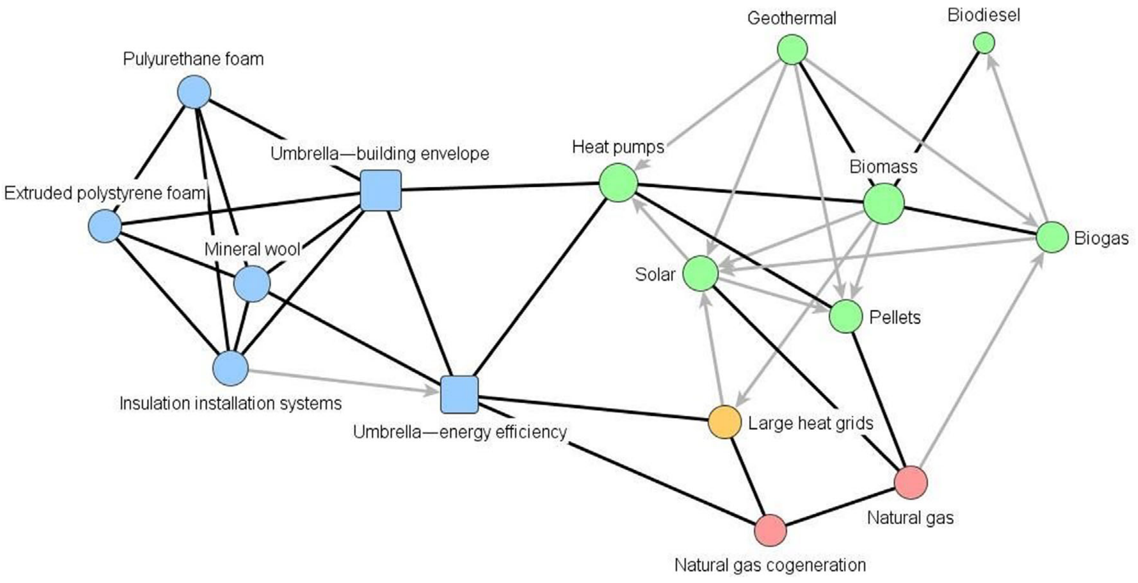

FIGURE 3 In the network, cooperation is indicated by black links in cases when interviewees stated that they cooperate with each other. A grey link indicates that only one representative of an industry association claimed a cooperative relation existed. Industry associations that promote a single technology are represented by a circle, whereas umbrella industry associations are shown as squares. The coloring of the industry associations is the same as in the dendrogram (Figure 2). Industry associations that belong to cluster A1 (insulation materials, dimension 1) are depicted in blue. Industry associations that belong to cluster A2 (renewable energy, dimension 2) are depicted in green. Industry associations that belong to cluster B (efficient fossil fuel, gas grid, heating grid, and long-term renewable infrastructure, respectively dimensions 3, 4, 6, and 7) are depicted in orange and red.

completely aligned concerning their prioritized technological dimensions. By contrast, in subcluster A2B only two groups have a dissimilarity score of 0. None of the other industry associations are completely aligned.

In the theory section of this paper (Section 2), we have elaborated on the expectation that actors in close proximity to each other in the solution space will be more inclined to cooperate than actors who are farther apart. Based on this expectation and the data displayed in the dendrogram, we expect cooperation between the actors in clusters A1, A2 and B. We expected that this would become visible in the cooperation network, which is presented in the next section. Furthermore, we expected that the cooperation density between the actors in cluster A1 would be higher than the cooperation density between the actors in cluster A2, due to the higher fragmentation in subcluster A2 than in subcluster A1.

4.4 | Cooperation clusters among technology industry associations

Figure 3 shows the cooperation network among the analyzed technology industry associations. The network is based on network data that were collected as part of the interviews. Structures in the dendrogram reappeared in the industry associations' cooperation behavior. First, we expected that clusters A1, A2, and B depicted in the dendrogram would become visible in the cooperation network. As expected, the main clusters A (A1 blue, A2 green) and B (red/orange) were clearly visible (Figure 3). In Figure 3 actors in cluster A1 appear on the left side of the cooperation network, actors in cluster A2 congregate in the upper right-hand corner, and actors in cluster B are located in the lower right-hand corner of the cooperation network. Furthermore, we expected the cooperation density between actors in cluster A1 would be higher than the cooperation density between actors in cluster A2 because the visions of the actors in cluster A1 were more aligned than the visions of the actors in cluster A2. The cooperation network confirms this expectation: Whereas cluster A1 features a cooperation density of 83.3%, cluster A2 features a cooperation density of 48%.[5]

Based on the vision-derived hierarchical clustering, we were able to predict the general coalition-building structures shown in Figure 3. However, the cooperation network shows one coordination anomaly that could not be predicted. The solar industry association aligns with the biodiesel industry association on more dimensions (four dimensions: 2, 3, 4, and 5) than it aligns with the natural gas industry association (two dimensions: 5 and 6) (see the data in Table 3). However, the solar industry association cooperates with the natural gas industry association and does not cooperate with the biodiesel industry association. This finding suggests that the proximity of visions of the future is only one indicator to predict cooperative behavior, but that it is possible that some vision dimensions are more important than others, such as when technologies are specifically complementary to each other, such as gas boilers and solar thermal heat panels, which in Germany are often used together. Another explanation could be that it is possible that other reasons not covered in paper are influential with regard to cooperative behavior.

5 | DISCUSSION AND IMPLICATIONS

The results of our analysis show that the German heating sector features a variety of technological solutions, as well as a variety of actors. The results also provide evidence in support of our main hypothesis, namely that industry associations cooperate with other industry associations based on shared visions of the future. The visions are substantially shaped by the characteristics of the technology in question. Arguably, most of the ties between the analyzed actor groups are likely to have been predictable based on the different industries that the interviewees represented, and the actors' material interests. However, if predictions had been based only on the actors' direct material interests, we would have expected that the biogas and the natural gas group, as well as the large heating grids and geothermal group, would have indicated reciprocal cooperation, since these groups have shared material interests. The biogas group and the natural gas group both require gas grids for their operations, and the large heating grids group and the geothermal group have complementary material interests, since industrial-sized geothermal applications require large heating grids. Since these groups did not show reciprocal cooperation, it can be assumed that using visions as proxies for cooperation is more insightful than relying solely on material interests.

In addition to the confirmed hypothesis that actors cooperate in their actions based on their visions of the future, we further hypothesized that the cooperation in fragmented socio-technical systems would reflect that fragmentation. In turn, fragmentation of actor networks is likely to impede the emergence of dense cooperation networks that drive institutional change. This hypothesis could not be confirmed, since even though some clusters were able to be predicted based on the visions, the visions supported by the actors in the sample were quite fragmented. This resembles the initial observations of the German heating sector by Wesche et al., 2019. Such a plethora of visions is likely to be typical of transitions, especially of such fragmented sectors as the German building sector.

From the transitions literature, we know that a clear vision to which relevant actors can relate is necessary in order to accelerate a sustainability transition. For example, Loorbach (2007, p. 11) states that transitions "need to be based on a shared sense of urgency, on forceful and inspiring long-term sustainability visions and on societal innovation strategies." Similarly, Hekkert et al. (2007, p. 423) implicitly consider visions as instruments of "priority setting and thus [defining] the direction of technological change." Hence, the lack of a vision that can work as an umbrella is likely to be counterproductive to the emergence of a single vision that could unite a sufficient number of actors, who could then develop the force needed to bring about institutional change. Hence, fragmentation of the actor landscape is likely to perpetuate the current institutional lock-in. To escape the lock-in, we suggest that actors should become institutionalize brokers who explicitly look for overlaps in visions and use them as the starting point for cooperation. Their main task would be to find a balance "between multiple priorities, interests and knowledge pools for creating a shared vision and activities to facilitate transitions" (Kivimaa, Boon, et al., 2019 p. 1067). Furthermore, these findings on how fragmentation influences cooperative behavior in the German residential heating system may indicate that different and varying fragmentation levels might also influence the institutional change dynamics in other socio-technical systems and the pace of transitions in those systems. The data indicated that highly fragmented systems could lean toward a slower pace of institutional change and transitions dynamics. However, the statement should be treated with caution, and it is advisable to be careful with generalizations, as the data presented and analyzed in this study are limited, and similar studies of other socio-technical systems and larger datasets are not yet available. Such studies could constitute a valuable research avenue in order to continue building a better understanding of the dynamics in socio-technical systems with different levels of fragmentation.

Furthermore, our data revealed that low-carbon niche technology industry associations sometimes coordinate with incumbent industry associations, such as found between the pellets group and the natural gas group. Theoretically, this can be explained as hypothesized with overlapping vision dimensions, but it suggests that not all dimensions influence cooperation behavior at the same level of strength, since the solar industry association overlapped with the biodiesel association to a greater extent than with the gas industry association, but still chose to cooperate with the gas association instead of with the biodiesel association. Hence, it can be assumed that some dimensions are likely to influence cooperation behavior more strongly than others. Hence, too, another valuable research avenue would be to identify what impacts the strength of a dimension and how this could be better understood. Furthermore, such observations might provide insights into niche-regime interaction. For example, Smink et al. (2015) suggest that incumbents use strategies ranging from "providing information and arguments to policy makers and the general public, as well as strategically setting technical standards" to keep sustainable innovations "on a leash." However, the behavior observed in our study may indicate that incumbents may also be strategically seeking, through bilateral cooperation, to stop the emergence of larger coalitions of niche actors. However, since we did not analyze incumbent strategies in particular, such strategies could be analyzed in future research, as well as whether there is evidence that could potentially be added to an incumbent strategy.

Empirically, with regard to the overall transition, cooperation between niche actors and incumbent actors is not necessarily helpful. Rather, it is likely to undermine the emergence of meaningful cooperation and thus hamper the emergence of a powerful pro-sustainability coalition.

6 | CONCLUSIONS

In addressing the two research questions in this paper (Section 1), we have aimed to contribute to a better understanding of what determines cooperation and how cooperation in fragmented socio-technical systems is likely to be fragmented, which could have adverse effects on institutional change that would otherwise accelerate transitions. Based on our research, we have shown that a wide range of technologies exists in the German heating sector. Each of these technologies is represented and promoted by different industry associations. The actors in these associations have visions of the end state to which they aspire.

The study findings show that similarities in the visions regarding desired end states of sustainability transitions may help to predict main cooperation clusters. We have also shown that technology characteristics are a key determinant of these visions of the future. Empirically, the study findings show that the large variety of technologies is reflected in a multitude of visions, which leads to a fragmented cooperation landscape. Cooperation between niche interest groups is based on technological symbiosis along specific dimensions. In our case, a large cohesive pro-transition coalition that unites all pro-sustainability niche interest groups did not emerge. The formation of such a cohesive coalition is undermined by continued cooperation between low-carbon niche industry associations and incumbent fossil-fuel industry associations. The lack of a strong low-carbon coalition is likely to contribute to the perpetuation of the institutional and political lock-in. As a result, a low-carbon heating transition will remain stalled. We suggest that for strong, powerful, and cohesive low-carbon coalitions to emerge, actors supporting low-carbon solutions and policy entrepreneurs need to find a common vision (or "shared ground") that can unite a wide variety of actors.

Theoretically, this paper contributes to a better understanding of institutional change in socio-technical systems in general and in fragmented socio-technical systems in particular. The analyzed data suggested that cooperation dynamics and thus institutional change in socio-technical systems can be influenced by the level of fragmentation of a socio-technical system. The outcomes of the study indicate that cooperation in rather fragmented systems is likely to be fragmented too, which could lead to a slower pace of institutional change and hence slow transitions dynamics. However, for the purpose of generalization, there is a need to account for the limited number of interviews and single case study research design.

Apart from the theoretical and empirical contributions, a novel approach was used to analyze and visualize visions and cooperation-related data. Visions were mapped using the idea of a solution space and visualized in a dendrogram based on clustering the visions-related data, which proved to have predictive capabilities for emerging cooperation. While the data analyses proved quite insightful, we suggest that the method could be further developed and the empirical robustness of the results could be improved by replication in similar studies in other transitions settings. Furthermore, we only focused on the technological dimensions of envisioning a transition future, yet we are aware that actors may envision futures that are not necessarily based on technological dimensions alone. The analysis was further limited by the number of interviewees. The results would have benefited from a larger sample of industry associations. However, we are certain that 16 of our original 22 datasets were adequate to produce sufficiently reliable data from which to derive the insights presented in this paper. Furthermore, in this paper we have treated the interviewees as representing the views of the respective organizations. This has some limitations and therefore, to obtain a more comprehensive assessment, ideally several more interviews per industry association would have been needed. Furthermore, the visions presented by the interviewees appeared to focus on technological dimensions. Potentially, the visions would have been richer in terms of socio-technical elements if the interviewee selection had extended beyond groups with only technological interest.

We see valuable avenues for further research on the emergence and maintenance of sustainability transitions related to coalitions. In particular, it would be interesting to learn how representatives of industry associations can engage in institutional work, such as building visions that resonate with a variety of potential coalition members. Also, it would be of interest to learn about the obstacles that policy entrepreneurs face in transitions settings and how such obstacles could be overcome.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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ENDNOTES

[1] In spring 2019, a new industry association was established that promotes thermal insulation materials made from renewable sources. It was not included in our research because it was established after the data collection had been completed.

[2] The list also included three industry associations that did not agree to be interviewed. However, since several of the interviewees indicated coordination with those actors, they were kept in the dataset to provide a more comprehensive picture. Interview requests were also sent to the umbrella industry association for heating and gas furnaces, and to the German Association of Energy and Water Industries (Bundesverband der Energie- und Wasserwirtschaft). There were no responses to the requests.

[3] In the theory section of this paper (Section 2), we consistently refer to "dimensions." We suggest that the ways transitions unfold can be envisioned based on technical and non-technical dimensions. In the study on which this paper is based, we analyzed the coordination behavior of technology-related industry associations. Accordingly, in the remaining part of this paper, we focus on technical dimensions.

[4] All quotations from the interviewees presented in this paper have been translated from German into English by the paper's authors.

[5] The coordination network shown in Figure 3 is a binary network. The density of such a binary network is calculated by dividing the total number of realized ties by the total number of possible ties. In cluster A1, 25 of 30 possible links were realized (83.3%). In cluster A2, 20 of 42 possible links were realized (47.6%). Since cluster B encompassed only three industry associations, we did not calculate the coordination density for that cluster.

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APPENDIX A

Questions for semi-structured interviews during which interviewees were asked about their visions for heating transition in Germany:

1. What is the heating transition for you as a representative of the [name] industry organization?
2. What do you envision the heating sector should look like in the future?
3. What is your position as an industry group on the heating transition you have outlined in your vision?
4. Why do you want the specific heating transitions that you pointed out in your response the previous question?
5. How can the technologies that you promote contribute to the heating transition?
6. How do you assess the advancement of the German heating transition?
7. What do you base this on?