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Sustainability transitions in local communities: district heating, water systems and communal housing projects

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Abstract

Sustainability transitions take place across geographical and political levels. Services such as energy supply, water supply and wastewater management or housing are part of daily life have to be provided at the district level within larger urban governance structures or by smaller rural administrations. However, relatively little attention has been given to the analysis of these local structures. This paper reviews case studies of niches in the areas of district heat networks, communal housing projects for the elderly and sustainable water/wastewater management. The paper addresses the following research questions:

1. What are the similarities and differences in the case study's drivers and barriers that have arisen between the fields of action and what conclusions can be drawn from these insights in order to maximize success factors or to minimize obstacles in advance?
2. What are the key factors for transition, also with regard to the synergies of the three fields of action?
3. What is the stage of development of the niches? Are they in a transition process or not?

District heat networks are established as a niche, but given the current policy and financial environment are developing very slowly. Communal housing projects are a small part of the overall housing market, but the niche is stable and growing. Waste water separation and new rain water management systems are developing as niches, but the centralised management of decentralised waste water treatment has so far only been adopted in a few cases.

These niches are all critically dependent on support from the district authorities. High complexity and inconsistency in legal frameworks, and missing financial resources present significant barriers for innovative niche projects.They usually require new, specific financial support to enable the change from conventional systems. These groups face a difficult period of developing their expertise in planning and management and often require financial support and advice. Consultancy networks - if available - have been shown to be important in enabling such projects to establish themselves. As all three case studies rely on infrastructure components, stakeholders need to consider windows of opportunities for innovation. Acceptance and trust are additional factors influencing the projects. Therefore, constructive and goal-oriented 'interaction' and communication between the stakeholders on district and project level are key factors for success. It is important to share data and information to guarantee an early integration of important stakeholders, including the public.

Projects in all three areas have the ambition of improved sustainability, although data on the actual impact is limited. The housing projects can be argued to contribute to sustainability in all three areas: environmental, social and economic. The district heat networks are supposed to reduce environmental impacts compared to current systems, but there was insufficient monitoring information to be certain that this is the case. The alternative water management systems all make a contribution to environmental sustainability and can be shown to be economically viable. If successful, projects in all three sectors can strengthen local social structures. Economic sustainability is a necessary condition for the success of projects in all three areas and this requires financial support and resources that are not available through the conventional housing, energy or water services market institutions.

While projects on district and household level are fundamental to a sustainability transition, efforts for up-scaling their impacts (Luederitz et al. 2017) are just as important. The challenges for actors on local to global scale are to learn from different narratives and adapt different perspectives, build unconventional alliances and collaborations to implement innovative, creative and intelligent solutions for a sustainability transition on a larger scale (Luederitz et al. 2017; Wittmayer et al. 2016; Brown et al. 2013).

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1 Introduction

Sustainability transitions take place across geographical and political levels. An important area of study is the city/regional level and the focus of literature in sustainability transitions has turned from the national to the city level as a critical field (Markard et al. 2012; Hodson, Marvin 2010; Bulkeley et al. 2011). However, changes in practices and institutions are enacted on and affect the lives of individual people and households. Services such as energy supply, water supply and wastewater management or housing are part of daily life. These services and systems have to be provided at the district level within larger urban governance structures or by smaller rural administrations. However, relatively little attention has been given to the analysis of these local structures. Smaller configurations, whether defined in terms of administrative boundaries (e.g. boroughs, districts, towns, villages), geographical boundaries (e.g. the land between the rivers) or shared values (e.g. community) are not treated in detail (Wittmayer et al. 2014; see Schäpke et al. 2017).

While place-specificity is recognised as a key factor in sustainability transition research (Hansen, Coenen 2015), a gap can be identified in the understanding of the way it influences transition processes (Fastenrath, Braun 2018). The actors who are engaged in more fragmented structures, e.g. at the urban district or neighbourhood level within larger urban governance structures or smaller rural administrations have not been extensively studied. A systematic understanding of their roles and potential impacts as well as tensions and restrictions they face is currently lacking (Heinrichs, Laws 2014). This is in contrast to recent calls for a stronger focus on the local and municipal level (Kemmerzell et al. 2016).

This paper therefore considers the development of niches that have the objective of developing sustainable alternatives at the local level i.e. on the district and household level as the actual implementation of major decisions taken by national, subnational or international level (Dütschke, Wesche 2018). The Multi-Level Perspective on transitions (MLP) (Grin et al., 2010) is used as the framework for the analysis and to make the connection to larger scales (Lüdeke et al. 2004).

It compares the results of case studies in the three fields of energy, water and housing in Germany. Three particular areas were chosen to enable concrete analysis of niches that have the goal of achieving a more sustainable lifestyle. The aim of focussing on multiple sectors is to avoid separating "policy fields" and

compartmentalisation as these systems are generally highly interconnected at the urban district and neighbourhood level (Späth, Rohracher 2015). District heat networks were identified as a system that has the potential for energy provision to local communities that enables lower associated air and greenhouse gas emissions and enables cooperation within communities. In communal housing projects, there is a change towards new forms of institution, especially for elderly people. Local water and wastewater services offer new modes of provision and the possibility of decentralised and self-contained systems. These three areas all involve housing and infrastructure systems for housing and are regulated and planned at the district or community level.

The paper addresses the following research questions:

1. What are the similarities and differences in the case study's drivers and barriers that have arisen between the fields of action and what conclusions can be drawn from these insights in order to maximize success factors or to minimize obstacles in advance?
2. What are the key factors for transition, also with regard to the synergisms of the three fields of action?
3. What is the stage of development of the niches? Are they in a transition process or not?

The paper summarises the three cases (see Wesche, Dütschke, Friedrichsen, 2017; Peters et al., 2017; Hacke, Müller, Renz, 2017 for more detail) and applies the typology of systemic failures influencing the adoption of sustainable technologies developed by Woolthuis et al. (2005) and adapted by Negro et al. (2012). In a comparative analysis, common factors and the potential for synergies between these three areas are identified. Barriers to the adoption of new systems and synergies are analysed. The factors influencing the development of niches and the MLP serve as a common basis for comparison. It investigates the relationships of sustainability niches to local governance and policy structures in particular. Relationships to higher-level institutions and governance forming the regimes in these areas are also considered.

2 Methodology

2.1 Multi-level perspective

The Multi-Level Perspective on transitions (MLP) is one of the key concepts in transition studies (Geels 2002; Geels, Kemp 2007). To explain dynamic transition processes it combines theories from different disciplines, e.g. evolutionary economics (Nelson, Winter 2009; van den Bergh, Gowdy 2000), the theory and sociology of innovation and technology (Porter et al. 2004; Rip et al. 1995; Truffer et al. 2008), and institutional theory (Geels 2004). Transitions in this context are defined as fundamental shifts from one socio-technical regime to another. The MLP concept argues that transition processes occur within and between three levels, i.e. niches, socio-technical regimes and slow moving general socio-technical developments of the social, economic and technical landscape. Socio-technical regimes embody the institutional structure of existing systems, setting the dominant cognitive, regulative and normative rules and regulations (Geels 2002; Geels, Schot 2010). Regimes are dynamically stable and their maturity results in path-dependencies and incremental innovations. In contrast, niches are the locus for radical innovations, usually found in protected socio-economic spaces characterized by a low level of stability (Geels, Schot 2010). The MLP is applied as a common framework to compare the development of niches found in the three case studies summarized in the paper (see Wesche et al. 2017; Peters et al. 2017; Hacke et al. 2017 for more details).

2.2 Factors influencing sustainability transitions

To identify possibilities for action in niche development at the urban district and neighbourhood level, this paper combines the MLP scheme with a typology of systemic problems introduced by Woolthuis et al. (2005) and adapted by Negro et al. (2012).

Negro et al. (2012) reviewed the literature on systemic innovation failures in renewable energy from a Technological Innovation System (TIS) perspective, which identifies barriers to the uptake of alternative, sustainable technologies in innovation systems. The TIS analysis can be interpreted as a framework for the analysis of niches while the MLP provides a structure for considering the interactions between the niche(s) and regime under the influence of the socio-cultural landscape (Köhler et al. 2016).

The typology of systemic problems developed by Woolthuis et al. (2005) was used by Negro et al. (2012) to develop the typology of factors that influence the development of innovation systems shown in Table 1. In the synthesis of the district heating, communal housing, and sustainable water systems discussed in this paper, the systemic problems are interpreted as influencing factors that impede or foster the development and diffusion of these niches (see Wesche et al. 2017; Peters et al. 2017; Hacke et al. 2017 for more details).

Table 1: Factors influencing for niche development on district and neighbourhood level (adapted from Negro et al. 2012)

Factors	Description
Formal institutions	… formal, written codified rules, laws and statutes and standards. These reflect political priorities and technological developments.
Informal institutions	… informal, unwritten rules, which arise from norms, values and local culture (e.g. acceptance of new systems, understanding of the new systems and their requirements).
Interactions and organisation	… interactions between actors, whether supportive or unsupportive for the development of the niches.
Market structure	… organisation and structure of the market (e.g. competitiveness, strength and role of the established actors).
Capabilities & Resources	… competences, knowledge and resources of the actors in the development of the niche.
Infrastructure	… requirements for infrastructure and natural resources (e.g. area of land required).
Other	… e.g. windows of opportunity, influences from the landscape level (in the sense of the Multi-Level Perspective.

3 Findings from case studies

For all three sectors, the relevant regime is described based on a literature review and 16 cases for in depth analysis were identified. Expert interviews with actors in the 'Kommunen' or districts were undertaken in 2016-2017. Interviews were also conducted with actors in national networks. The interviews (67 in total), were structured around the niches chosen and the factors influencing their progress and their interactions at the urban district level.

3.1 District heat networks

Space heating is a major part of energy consumption, being 27% of the total in Germany in 2017 (BMWi 2016). However, the German 'Energiewende'' can so far be described as mainly an electricity transition. A transition in heat provision is also needed. Therefore, district heat networks are considered to be an important part of the 'Energiewende' - the transition to a sustainable energy system in Germany. Local heat networks are understood as sustainable small grid-connected heat supply systems that use innovative means to provide heat, e.g. renewable source or waste heat. They are characterized by lower carbon dioxide emissions than conventional systems that run on natural gas or heating oil. Here, the heat networks comprise all integrated heat sources, transmission lines and transfer stations. The focus on small heat supply systems means that a minimum of about 15 buildings are connected to the grid. These systems enable the integration of renewable energy technologies into energy systems. This includes houses that cannot be insulated e.g. buildings under preservation protection.

However, these systems have not been widely adopted (Wesche et al. 2017). They are often most effective at a district level and have to be organised at this level (Wesche et al. 2017). Table 2 provides an overview of district heat networks investigated in the case study.

Table 2: Overview district heat networks (Wesche et al. 2017)

Case	Opened	Type of district heating system	Organisation	Type of housing	Financial support
Schlöben	2011	Biogas	Cooperative	Rural / existing housing stock	EFRE, KfW-Map, ILERL
Bonndorf	2014	Industrial waste heat, wood pellets	Run by the manufacturer	Rural / existing housing stock	N/A
Dollnstein	2014	Solar thermal, Heat pumps, district heating, network with variable temperatures	District council (Kommune)	Rural / existing housing stock	N/A
München Ackermannbogen	2007	Solar thermal, Gas, large heat storage unit	Community energy provider	Urban / New build	Solarthermie2000+
Wüstenrot	2016	Heat collector in agricultural land with heat pump and low temperature network	N/A	Rural / New build	Research project
Police Academy Biberach	2014	Virtual power station, district heating, heat pump, storage unit	Land BaWü, Generation company	Rural / existing housing stock	N/A

Level of Diffusion

There are some individual projects in Germany, but there is not a widespread diffusion of the technology and growth through new projects is slow. The proportion of heat supplied by renewable energy grew by 2.8% from 2009 to 13.2% in 2015 (BMWi 2016, p. 15; Wesche et al. 2017). The overall potential of district heat networks is limited in rural areas by a lack of sufficient heat demand and in built-up areas by a lack of space for the heat infrastructure.

Main factors influencing the development of the niche, main barriers

The development of a district heat network requires an enthusiastic team to start the project that is trusted by the local community and has the support of the district council. It also requires the availability of a heat source and a suitable site for the equipment. Problems with the local conventional energy system (e.g. a need

to replace ageing conventional systems) and a high level of awareness of renewable energy systems and the climate change issue in the community are likely to provide a supportive environment.

There are a series of barriers to the wider deployment of district heat systems. These systems often have a low priority in local or district development plans and budgets. The reasons for this are the lack of pressure from national or regional policy, lack of financial resources at the district level and an inconsistent structure of economic incentives, which partly support fossil fuels. The current (2016-2018) historically low energy prices for heating oil for households also means that there is little financial incentive for households to look for alternatives to their conventional (fossil) energy and heating system.

3.2 Communal housing projects for the elderly

Communal housing projects are organised by alternative forms of community, which include features of communal living that is self-organised and organised for mutual support. They involve participation of the households in decision making and usually set the objective of environmental standards above the market average (Brech 1999, Tornow & Dau-Schmidt 2012). They have had to develop new ways of organising, financing, building and use of the housing. Communal housing projects are a reaction to limitations of local social networks as a result of long term trends to individualisation, demographic change and difficulties in finding affordable housing.

The examples chosen have the following features (Hacke et al. 2017):

- The households are not related to each other.
- Households live together in a single location with their own living space and communal facilities.
- There is an expectation that all households are active and mutually supporting in everyday living.
- Communal life and at least a part of the property management is self-organised in a democratic way within the project.

The projects are summarised in Table 3.

Table 3: Summary: Communal housing projects for the elderly

Project	No. of flats	Finance	Age	Care provision	Project type	Growing/ Declining city	Location
Generationenhof	37	R	old and young	Yes	New	+	Landau, Rhineland-Palatinate
Tortwiesen Au	30	O, R, SR	old and young		New	-	Heikendorf, Schleswig-Holstein
Haus Mobile	24	O, SR	old and young		New	+	Stuttgart
Wogeno IV	28	R, SR	old and young		New	+	Munich
Gemeinsam älter	11	SR	60+		Re	-	Wilhelmshaven, Lower Saxony
Gingko 1	26	O, R	50+	Yes	New	+	Langen, Hesse

Legend: Finance: O: owner, R: rent, SR: supported rental; Project Type: Re: rebuilt

Level of Diffusion

There are an estimated 2,000 - 3,000 (in 2016) communal housing projects in Germany (Fedrowitz 2016: 11) and although the number is increasing it remains a very small part of housing projects in Germany (Fedrowitz & Matzke 2013: 179; Ginski & Schmitt 2014; Brech 1999). Projects for the elderly have shown a particularly strong growth since the 1990s (GdW 2013: 10; Fedrowitz & Gailing 2003; Tornow & Dau-Schmidt 2012) and multiple-generation housing is also increasing.

Main factors influencing the development of the niche, main barriers

Housing projects that enable social networks, mutual support and democratic decision making are seldom generated by the housing market (Hacke et al. 2017).

Market prices in the larger urban regions are increasing (Statistisches Bundesamt 2015) and for lower income groups it is getting more difficult to find affordable residential spaces (BBSR 2015). Therefore, such projects often require the support of local government combined with community engagement. They are often initiated by local community actors, who then have to develop or find the expertise to carry out a housing project. Furthermore, for these projects the challenge is to

develop the necessary legal and project management skills to set up an organisation and collect and manage the capital. The cultural distance between the established housing developers and markets and community housing is large. There are few suitable sources of advice or consultants who are competent in communal housing projects.

The projects themselves do not exert pressure on the housing regime or policy, being self-run and often too busy managing their own project for the community members.

However, there is evidence in the cases studied of some opening up of the regime. In some regions, professional advice and consultancy and some organisations specialising in community housing projects have developed. For example, Hamburg, Berlin as well as North Rhine-Westphalia and Schleswig-Holstein have supported the development of a network of consultancies. In other areas, there is still a lack of professional legal and financial advice. Financial support for the acquisition of land is limited to a few cities. Well-known examples are Hamburg and the city of Munich. A few organisations specialising in community housing developments have been established. They provide the specialist expertise, although the financing is still dependent on project founders (Hacke et al. 2017).

3.3 Local sustainable water management

The context for water supply and wastewater treatment is changing in various ways. Impacts of climate change like extreme weather events, changes in rainfall quantity and distribution are affecting water systems in Germany. Various regions in Germany are experiencing a decline in population, with a reduction in the number of users of water systems, while the continuing increase in the area of built-up land and transport infrastructure is increasing the area requiring water supply and sanitation (Hiessl et al. 2012; Hillenbrand, Hiessl 2006; Hillenbrand, Klug 2010). There are also new environmental standards, for example concerning energy efficiency of water management systems (biogas, heat recovery) or the control of micro-pollutants. There is a considerable requirement for the adaption and renewal of water infrastructure, such that district authorities (Kommune) face the challenge of developing a strategy for modernising their water and sewage systems (Bolle, Krebs 2015; Zimmermann et al. 2014; Hiessl et al. 2012). There are various new system concepts for meeting these challenges. Three of the most important technologies, which form niches in the water and sewage systems are new sanitation systems, integrated rainwater management and centrally managed decentralised wastewater treatment.

New sanitation systems (DWA 2008) increase the separation of wastewater flows (e.g. into grey and black wastewater) to enable the recovery of energy, water and nutrients. These require major changes in the layout of piping and systems inside and outside buildings. They are often laid out at the district level. The case chosen was the wastewater system in the ecological housing project at Flintenbreite in Lübeck, established in 2000. This project implemented a system for separation of rainwater, grey (bathroom, washing machine) and black wastewater (toilet, kitchen) and organic waste. This enabled differentiated treatment, recovery and utilisation of the nutrients of value in household wastewater including organic waste. The system included vacuum toilets. It was one of the first applications of wastewater separation.

Sustainable or integrated rainwater management has the objective of management systems that are compatible with the local environment and ecosystems in urban settings. Local natural water circulation processes and resources should be retained. Rainwater runoff should be reduced or delayed through storage or sinks, to reduce the flow through drains and hence reduce flooding. Rainwater should also be made available for use in households. While rainwater systems only form part of water infrastructure, they have impacts on the planning of roads and the built environment. As a case to study this approach Ems cooperative "15 in 15" was chosen.

Centrally managed decentralised waste water treatment are intended to counter the criticism that decentralised waste water systems are not operated and maintained to the necessary standards for safe and reliable services. This enables areas with low densities of occupation or decreasing population to develop a sustainable, cost-efficient and flexible wastewater management system. Two projects, namely AKWA Dahler Feld and z*dez, were studied in this field. Table 4 summarises the case studies in sustainable water management.

Level of Diffusion

In contrast to the other two areas, the water cases cover a range of fields of application. All three types of systems have been successfully demonstrated, but the further application of these concepts is still limited.

The new sanitation system project at Flintenbreite was a successful demonstration that has led to a few further projects and also the development of new regulatory standards, e.g. DWA A 272 (DWA 2014).

Table 4: Summary: Innovative water management projects

	Status	Financial support	Status of Stakeholders	Main Goals/ Motivation	Comments
New Sanitation Systems					
Lübeck Flintenbreite	P	yes	new	E, R	Delay due to change of project management
Sustainable Rainwater Management					
Ems cooperative "15 in 15"	P, D	yes	partly new	L, M, C	
Centrally operated decentralised wastewater systems					
AKWA Dahler Feld Selm, North Rhine-Westphalia	P	yes	Association	L, M, CR	Management organisation, in 2nd decade of operation
"z*dez" Baden-Württemberg	P, D	yes	new	L, M, CR	

Status: P: Pilot project, D: Diffusion

Main goals: E: Energy efficiency; R: Resource efficiency; L: implementation of legal requirements, M: Water management; C: Climate adaptation; CR: Cost reduction

The EGLV (Emscher Genossenschaft Lippe-Verband) integrated rainwater management project has received more widespread attention, with many contacts to other regions in Germany. The concept of reducing the urban area that is sealed and generates rainwater runoff has been taken up in other districts (Kommune).

The centralised management of decentralised water treatment systems has not been widely adopted so far. The interviews indicated that users who are prepared to adopt such a system also prefer to manage it themselves, while there is little political will at the district council level to encourage this type of solution.

Main factors influencing the development of the niche, main barriers

The new water treatment systems described above face considerable barriers to their diffusion. For instance, they require support at the district governance level, but these ideas are not yet widely accepted as suitable solutions for upcoming challenges (demographic change, climate change etc.). The legal structure of water treatment requires modification to support these alternatives. Because water treatment is a basic service (like energy provision) which must be provided with very high reliability, it is carefully regulated and this is therefore a further barrier to the implementation of innovative approaches. There is also a lack of

coordination at the district level between the complex array of stakeholders: town planning, local agriculture, housing, households, insurance, emergency services etc.

The economic viability of alternative systems must also be demonstrated for further projects to be undertaken. The new projects are very different to the old systems, which makes the financial assessment complex and therefore uncertain, which is also a barrier. Another hindrance for diffusion is that alternative systems often require the adaptation of the conventional or the development of new business models.

The relative success of the new rainwater management schemes does not face all these barriers. They are primarily enacted by local government officials and planners over a long timescale and are part of public infrastructure provision. They can be incorporated into town development plans, which then form part of the context for housing, rather than having to be adopted as part of each individual housing project. The limitation is that town planning is a long term task, partly because the built infrastructure is long lived, such that changes are slow. The adoption of new schemes is also heavily dependent on the enthusiasm and resources of local councils, both in terms of developing expertise in the alternative systems and in budget allocations.

4 Review of factors influencing niche development at the urban district and neighbourhood level

In the following section, the results of the comparison between the case studies based on the factors introduced in chapter 3 is given (Table 5).

Table 5: Overview of factors influencing the success of niche development in three sectors: district heating, water infrastructure and housing

	Definition	Energy: District heating	Water infrastructure	Housing
'Hard' Institutions	Formal, legal requirements, regulations, standards etc.	Numerous legal instruments and support mechanisms; difficult for local actors to apply because of the complexity; Some conflicting incentives e.g. support for fossil fuels and continuing support for fossil heating systems. Lack of direct Statutory requirements (e.g. in heat systems planning, heat maps)	Innovative systems cannot be fully financed from current charges. Technical standards are still focussed on conventional systems. Increased complexity due to e.g. the increased number of relevant stakeholders is a barrier.	Requirements from Social, Communal, Property and tax law require creative solutions for specific projects. Housing requirements are not necessarily compatible, dependent on the project design. Support from the local administration often decisive. Some support at the 'Länder' (regional) level. Pre-existing housing development plans can be a challenge.
'Soft' Institutions	Informal rules and values, norms und culture	Differing responsivity from different social groups. Distributional justice in costs, possibilities/requirements for connection/compulsory connection depending on local (governance) culture and the assertiveness of decision makers.	Compliance with 'soft' institutions is improved in some new systems (centrally managed decentralised systems), can also be more difficult in other areas (restrictions on use of areas for water infiltration); actors tend to be resistant to change, as they are used to the current system. Changing behaviour is a challenge.	Strong motivation of project members. Successful process of team building is decisive. Experienced/established consultants can address limited trust of other actors (banks, local government).
Market structure	Market mechanisms, costs and value chains	Wide range of current and innovative technologies makes an overview of the market difficult. Higher involvement of tenants leads to split incentives. Recently installed conventional systems lead to path dependency and high opportunity costs of further investment.	Quasi monopoly market. no self-regulating market mechanisms. Structure of charges and fees as well as perhaps constitutions must be adapted.	Proof of members' own financial resources often difficult. Leads to unfavourable conditions for finance. Can be overcome by local authority support. Competition from development corporations. High land prices in cities. Projects as competition to home ownership, households with capital tend to prefer to buy their own home.

		Local government has limited control, decisions taken by individual households/ property owners.		
Capabilities/ Competences	Competences, skills, and resulting structures	Active stakeholder groups are necessary for projects to be realised. Cannot be created just through financial incentives. Local expertise and consultants are often lacking. Very limited resources and expertise in local government.	Very limited resources and expertise in the relevant stakeholders. Lack of specialist expertise in water management in general.	Lack of (legal) knowledge in project members is a challenge. Process of team building in the project needs to be managed.
Interactions	Interactions between social actors, the public and other stakeholders	Strong lobby and established networks of the conventional suppliers - local variation. Numerous individual decisions are required for project implementation (e.g. decision makers for connections, approval from local authorities). Weak networks in district heating (local government, suppliers, consultancy).	Establishment of networks and communications structures, including users and residents required.	Cooperation with conventional housing market may be required, but is not established. Cooperation with social services still weak. Consultants or contact with other projects or cooperatives is useful. Limited availability of consultancy.
Infrastructure	Technical, infrastructure and environmental situation.	*Windows of opportunity*, e.g. cyclical replacement of systems, new developments, renovation of local areas. Availability of space for heat sources/systems and available heat sources or laying of new distribution infrastructure	Many new concepts are especially favourable for operation without connection to local infrastructure. Long life of current infrastructure means system change is expensive; *windows of opportunity.*	Purchase of affordable land that is consistent with project aims; *windows of opportunity,* Particular challenge for pre-existing buildings.

With regard to **'hard institutions',** it can be shown that niches across sectors investigated are struggling with limited conformity of regulations and institutions of the present regime. Thereby, the specific challenges for niches differ for the different sectors. While in heat networks the number of different rules and requirements of incentives hinder a cost-effective implementation, profitability in the water sector is hardly possible due to an insufficient compatibility with current fees and charges. In the housing sector the high number of differing regulations and missing standard solutions present an obstacle to actors in practice with a lack of expert knowhow.

Concerning **'soft institutions'** there are often tensions between project teams and other stakeholders e.g. users and residents or other institutions such as banks. Consultants or other intermediaries are particularly important here if they are present. They are required to support the development of professional expertise in project teams to ease communication with other actors and represent the interests of the project. These services and sources of advice are less active in water than in heat networks and housing cooperatives.

'Market structures' are a challenge in all three area, but with differing severity. Path dependencies including established/regime institutions that support current systems often make the implementation of new systems difficult. The market structures in all cases investigated are not aligned with the needs of the niches. There is a lack of incentives or in the case of heating, an inconsistent policy and incentive structure.

Project groups have a lack of '**competencies and expertise'** in all areas. Projects are often initiated by potential users who have a vision of the new system or local members of the public or particular individuals in local government (e.g. local mayor or district council members), rather than specialist development organisations. The innovative systems are by nature less familiar to all actors, so that there is a lack of detailed knowledge, which has to be overcome during the project. Solutions are often project specific and not generalizable. Local government often lacks the expertise and specialist capacity, as well as the interest in developing the necessary knowledge, to support innovative niches.

There is a connection to '**interactions'** as an influencing factor. If the necessary networks have already been established, through contacts to similar projects, consultants or intermediaries of the current regime, e.g. the housing market, they can enable synergies to be realised and increased efficiency in the project. Networks therefore play an essential role.

'Infrastructure factors' have a similar influence to market structures: control over the current infrastructure or the ability to change are essential for successful niche projects. This raises the question of whether there are windows of opportunity that enable path dependencies to be overcome. The realisation of innovative concepts is easier in new building projects than in renovation. Most importantly, the selection of a site for development or redevelopment in the German context, where land is scarce and often expensive, presents an important opportunity. They can arise through the redevelopment of brownfield sites and also when infrastructure or buildings need to be renewed.

5 Synergies between the case studies and implications for change

The cases in cooperative housing, heat networks and sustainable water management all involve projects that are realised at the district (Kommune) level. Housing projects involve energy and water/wastewater systems and therefore offer the opportunity to combining the social objectives of cooperative housing with the new technologies and systems for energy and water/wastewater. An important aspect of these interlinkages is also the possibility of designing or refurbishing buildings to jointly optimise the efficiency of the energy demand from the housing with the heating supply and water systems. From a technical point of view, one possibility is the use of advanced decentralised wastewater separation systems to recover heat in a building. The layout of a housing project can also be optimised for the adoption of rainwater management systems as developed in the EGLV-ZVR and wastewater as in the AKWA Dahler Feld projects (Peters et al. 2017).

However, such combined projects would require the specialist competences to be developed in all three areas. They would involve the combination of public actors, citizens and commercial actors for finance, design, implementation and consultancy. The combined renewal of heat and water/wastewater systems requires a higher availability of investment funds for the single project than the renewal of the different types of system at different times. This is a considerable organisational challenge, especially considering the difficulties in developing specialist expertise that the housing projects have demonstrated and the limited specialist resources available to the planning authorities at the district level.

In the following, a summary of possible synergies between the cases and possible implications are provided.

'Hard Institutions'

The standards and legal frameworks set by the national government are an important contextual factor in innovation processes. Inappropriate standards and regulations constitute significant barriers for the alternative niche systems investigated in the case studies. The highly regulated nature of housing and infrastructure means that the authorisation of local government is required for a change to open up new perspectives for innovative solutions. In all three areas, there are technical, service-oriented and/or organisational solutions that, given effective management and operation, can meet the changing conditions while improving sustainability. The cases studied provide examples of demonstration projects that

function effectively. They can serve as a starting point for the development of supporting regulations and technical standards. As missing regulations and standards bear a high risk for innovative solutions, assurance opportunities on district level could serve as an interim solution.

'Soft institutions'

The case studies obtained different results concerning **'soft institutions'.** One common feature can be identified in tensions between project teams and other stakeholders e.g. users and residents or other institutions such as banks. Acceptance in the local community (e.g. users) can influence the outcome of project proposals. The advantages and requirements of the niche alternatives in all three areas need to be discussed and agreed with the local communities if they are to be accepted and hence supported. A lack of acceptance in the local community can lead to local government opposition, which will often halt a project. An example is the Bonndorf case for heat networks, where a local heating oil supplier argued against the alternative, leading to uncertainty in the local users. As a consequence, few users signed up for the alternative system (Wesche et al. 2017). Consultants or other intermediaries are particularly important here. They are required to support the development of professional expertise in project teams to ease communication with other actors and represent the interests of the project. These services and sources of advice are less active in water than in heat networks and housing cooperatives. To inform stakeholders and to qualify them for decision making in complex situations, education initiatives and information campaigns are required. It is necessary to specify the involvement of stakeholders in the process of sustainable development on district and household level.

'Market structures'

The support of the district authority is decisive in the provision of sites or buildings. This has to be complemented by financial support where market prices for land and buildings can often not be met from the capital resources of the community niche. The costs of rebuilding and restructuring the heat energy or water management system are not reflected in market prices for the heating and energy services to households, such that support programmes are required for such projects to be realised. These are sometimes made available from local authorities. Additionally, the market structures in the three sectors investigated are different. Therefore, tailored solutions for each sector are necessary as synergies are difficult to find.

Capabilities/Competences

The need for coordination across a community of households is a common feature. The stakeholders need to acquire new knowledge in technical and legal specialist areas and must at the same time develop new organisations. The stakeholders are similar for the three areas: householders and local communities, district councils, technical/standards authorities covering the various aspects of design, installation, operation and maintenance, construction companies and service providers. Specialist consultancies have an important role to play in providing specialist knowledge to the projects. A network of advice centres at the district level, comparable to "EnergieeffizienzExperten" (A German nationallyfunded energy efficiency analysis service, EnergieeffizienzExperten 2018) could help to pool relevant knowhow for a range of subjects. On the other hand, coupling different sectors in one expert network could help counteract compartmentalisation. Therefore, financial support to develop such networks from the government at the national level is necessary as local governance have limited financial resources (see for example Wesche et al. 2017, p. 58).

Interactions

The projects in all three areas require cooperation between the stakeholders involved. Successful projects demonstrate the development of a community spirit where people mutually support each other. The projects can also engender a realisation of the strength and potential for action of the local community, including financial resources. The realisation of this potential is then dependent on the support of the district administrations, their priorities and the attention given to such projects. An option could be the bloc of actors (lobbies) from different sectors focusing on sustainable niche/district/household development to work on regulations and acquisition of financial resources.

'Infrastructure'

The district heat systems and alternative water management systems are alternative concepts to the present (regime) infrastructures. They therefore represent a competitor to the regimes, which would reduce the effectiveness of the business model of the regime or replace it. The cooperative housing projects have mainly been developed to meet a new aspect of demand for housing: cooperative living in a common development and are therefore complimentary to the housing regime, with less interaction with the current commercial housing development sec-

tor. Path dependencies due to high investments in durable and reliable infrastructure components or the availability of affordable land are barriers to change (Hacke et al. 2017, p. 69; Wesche et al. 2017, p. 60; Peters et al. 2017, p. 41)

Windows of opportunity are therefore important for the implementation of sustainable infrastructure systems or services for communal housing. The realisation of innovative concepts is generally easier in newbuilding projects than in renovation. Most importantly, the availability of a site for development or redevelopment in the German context, where land is scarce and often expensive, presents an important opportunity. This can arise through the redevelopment of brownfield sites and also when infrastructure or buildings need to be renewed.

6 Discussion

Following the presentation of the main factors in the previous section, the results of the case studies are discussed and embedded conceptually in the following section.

6.1 Similarities and differences in the case study's drivers and barriers and key factors for transitions

In all cases investigated, legal frameworks and state subsidy programs in the category of **'hard institutions**' are complex and present difficult challenges to niche actors and projects. Nevertheless, it is possible to implement innovative solutions. However, bottom-up initiatives often lack expertise and require professional support to implement niche solutions successfully and to cope with uncertainties. Top-down initiated projects usually have more capacities and resources to ensure success. In the communal housing projects, professional consultancies and cooperation serve as a promising approach to support bottom-up projects. Another important factor found in all three case studies is the support of innovative niches through district authorities due to public interest. To sum up, high complexity and inconsistency in legal frameworks, and missing financial resources present significant barriers for innovative niche projects.

Acceptance and trust are the main factors driving the projects in the case studies on the level of **'soft institutions'**. It became clear that different actors are relevant for different sectors. In all three case studies, the support of municipal stakeholders is vital for success. In the heat and water sector, the local community and their attitude toward new technologies is another important driving or restricting factor for niche development. It can be supported through several measures, e.g. public information and communication activities. In the water case study, technical codes provide little flexibility for municipalities to act. Furthermore, conflicts of interests between different stakeholders can inhibit a project's success. In the communal housing sector, motivation of project teams or sponsors is crucial for success. On the other hand, the reluctance of financial institutions, municipality and property developers to support project teams is a barrier to success.

Different **'market structures'** between the case studies show a wide range of different implications for project success. In the heat sector, high transaction costs and a resulting poor attractiveness for institutional investors, strong competition of systems based on mineral oil as well as a high proportion of tenants

(user/investor dilemma) in Germany inhibit the diffusion of sustainable heat networks. Furthermore, the complexity and versatility of different solutions and combination possibilities prevent scale effects and standardised incentives. In the communal housing sector, project success depends on the financial resources and equity base of the parties involved. Social housing promotion in this case can be a driving factor. In the water sector, quasi-monopoly structures set high obstacles for innovative solutions. Additionally, the level of charges is a key factor as low charges result in longer depreciation periods and therefore provide fewer incentives for new assets. For households, the willingness and abillity to invest or pay strongly depends on the individual case.

Adequate financial, tangible and personnel resources, knowhow and communication facilities present important **'capabilities and competences'**. A decisive inhibition factor is insufficient funding for niche projects: If adequate capital resources are missing, project realisation is unfeasible. Furthermore, expertise and knowhow are important for niche projects, which means sufficient availability of skilled personnel, access to (external) expertise, education and training. In the heat sector, new information and advisory opportunities for different stakeholders, e.g. municipal stakeholders, project developers and planers seem useful. In the communal housing sector, project members with strong organisational and communication competencies are important to success. In the water sector, exchange between project planers and practitioners should be fostered. Furthermore, hedging mechanisms in case of important stakeholder losses should be discussed. In particular, in case of insolvency of one actor or migration of skilled worker, consequential insolvencies of other parties or uncertainties for stakeholders should be avoided.

Constructive and goal-oriented **'interaction'** and communication between the stakeholders on district and project level are key factors for success. It is important to share data and information to guarantee an early integration of important stakeholders, including the public. In a process of stakeholder integration, different interests should be identified and integrated in decision processes. New forms of cooperation could be helpful. Confidence building and personal contacts are seen as important factors, as well as networks between successfully implemented projects and new projects. In the three case studies, interaction across local authorities to share experiences and knowledge across district borders is supportive for niche development. In the communal housing sector, the decisive role of consultancies throughout the entire project period should again be mentioned. So far, they can only be found in larger cities in Germany and partly in Schleswig-Holstein and North Rhine-Westphalia. Public funding based on fees

as part of construction financing could support these consultancy services. In the water sector, interactions between the parties serve as promoting or hindering factors. As the number of parties involved increases, the need for discussion and complexity rises. A lack of inter-divisional and interdisciplinary cooperation is considered an obstacle and an early integration of specialist authorities and approval agencies are important drivers for niche development.

In the heating sector, the status of the heating system investment cycle, availability of land, and potential competitive heat infrastructures are relevant influencing factors concerning the **'infrastructure'**. Thereby, identifying the status of the infrastructure investment cycle is especially challenging. To facilitate access to consumption and infrastructure data would be a supportive measure. In the communal housing sector, access to suitable land and its purchase prices are key infrastructure requirements for the success of niche projects. Furthermore, the implementation of a community-building architecture is important. In the water sector, path dependencies due to already existing, durable and proven infrastructure components are the most important obstacles for innovative solutions. In this case, windows of opportunities (e.g. upcoming renovation works) and the persuasion of important stakeholders seem to be indispensable for the implementation of niche solutions.

6.2 Stage of development of the niches

District heat network systems have not yet been widely adopted (Wesche et al. 2017). There are some individual projects in Germany, but there is not a widespread diffusion of the technology and growth through new projects is slow. The current situation in which contradictory policies provide incentives for conventional fossil fuel systems as well as district heat networks means that there is no strong driver for change. The conventional regime remains dominant, as low current fossil fuel energy prices (in 2017-2018) are a barrier to further diffusion of renewable alternatives. Therefore, the district heat network niche can be assessed as established, but prospects for growth are uncertain. The probability of an acceleration in uptake is low.

Cooperative housing projects for the elderly have shown a particularly strong growth since the 1990s and multiple-generation housing is also increasing. Despite this long term trend, they remain a very small part of housing projects in Germany. Important positive factors in the demand for such projects are the increasing number of elderly people who live alone and the lack of provision through the conventional housing markets. Networks of specialist expertise and

consultancies are developing and local authorities are often willing to support these projects. Therefore, the niche can be assessed as stable, with the prospect of further growth. This growth is unlikely to be rapid, because of the long timescales and organisational difficulties still faced by the stakeholders.

In contrast to the other two areas, the water cases cover a range of fields of application. All three types of systems have been successfully demonstrated, but the application of these ideas is still limited. The new wastewater separation system project at Flintenbreite was a successful demonstration that has led to a few further projects and also the development of new regulatory standards. The EGLV integrated rainwater management project has received more widespread attention, with many contacts to other regions in Germany. The concept of reducing the urban area that is sealed and generates rainwater runoff has been taken up in other districts (Kommune), with long term financial support for these projects. Therefore, these niches of sustainable water management can be assessed as entering a phase of growth, with a prospect of widespread adoption. The very long lasting nature of water supply and management infrastructures suggests that the transition process will unfold over a long period of time. The centralised management of decentralised water treatment systems has not been widely adopted so far. Since there is little political will at the district council level to encourage this type of solution, this niche can be assessed to be still in formation and the eventual outcome - growth or disappearance of the niche - is highly uncertain.

6.3 Impact of the case studies on sustainable development

The case study projects in all three areas have the goal of creating a more sustainable system. They have different emphases on the three pillars of sustainability (environmental performance, social sustainability and economic viability: OECD, 2005).

The communal housing projects have been developed to provide long-term housing in a supportive community i. e. social sustainability. They also have the ambition of being more environmentally sustainable, mainly through reduced energy demand and/or through adopting renewable energy technologies. Due to the numerous obstacles the project groups have to solve they often are not able to fully reach these ambitions. Furthermore, they have to provide a sustainable economic solution for the members of the cooperative, whether through individual

capital contributions or a capital structure that enables affordable rents and covers the costs. Hence, the housing projects have the potential to address all three pillars of sustainability.

The district heating projects have environmental goals as their primary objective: reduced CO_2 emissions and lower overall energy demand. They are intended to replace conventional systems with combined systems that have a higher system energy efficiency and use renewable energy sources. In order to be successful, they must also demonstrate economic viability i.e. sustainability, which is as noted above a barrier to the adoption of these systems in the current structure of economic incentives and regulatory institutions. Social sustainability has a lower weighting in these projects and is implicitly addressed as the reliable provision of a basic housing infrastructure. However, it should be noted that most of the cases were not closely monitoring their emissions performance or their energy efficiency, so the extent to which the environmental goals are being met is unclear.

In the area of sustainable water and sewage management, the new sanitations systems are designed to improve environmental performance by increased separation of wastewater flows, which enable the recovery of energy and nutrients. As with the district heating projects, projects have to be economically viable. The Flintenbreite case is an example of a viable system. The EGLV-ZVR rainwater management system addresses a different aspect of environmental sustainability, because it is intended to adapt to changing environmental (climate) conditions, but it also has the objective of using natural ecosystem processes to achieve a more resilient system with increased provision of local green spaces and access to water features. This also contributes to the quality of life in the district. This can be argued to be a contribution to the social sustainability of the district. The decentralised wastewater systems also have an improved environmental performance. A significant advantage of the centralised management is that it is easier to ensure that the technical and environmental improvements are reliably achieved. The AKWA Dahler Feld project also provided an economic incentive for the owner. The old system for which the owner was responsible was life expired and would have had to be replaced at considerable expense. The new contract was arranged such that the owner did not have to provide extra capital for the new system.

7 Conclusions

This paper has reviewed case studies of niches in the areas of district heat networks, communal housing projects for the elderly and sustainable water/wastewater management. District heat networks have not yet been widely adopted and diffusion is slow. There is a lack of clear incentives to overcome the barriers of high initial investment costs and the complexities of a change in the energy supply system. Communal housing projects for the elderly are a small but stable and steadily growing niche in housing provision. This is due to the increasing numbers of elderly people living on their own. New wastewater treatment with separating of grey and black wastewater, enabling heat and nutrient recovery have been demonstrated and are being adopted for a number of new projects. New rainwater management systems that reduce the sealed area in urban areas are diffusing across district authorities in Germany. The concept of centrally managed, decentralised wastewater treatment systems has so far been restricted to a few demonstration projects and has not been widely accepted.

These niches are all critically dependent on support from the district authorities. In terms of hard institutions, high complexity and inconsistency in legal frameworks, and missing financial resources present significant barriers for innovative niche projects.They usually require new, specific financial support to enable the change from conventional systems for providing the services. At the same time, projects are often initiated by groups of people who want to have a different way of living to that offered by the market for conventional housing. These groups face a difficult period of developing their expertise in planning and management and often require financial support and advice. Consultancy networks have been shown to be important in enabling such projects to establish themselves. Furthermore, education, information and knowhow are important drivers for change. As all three case studies rely on infrastructure components, stakeholders need to consider windows of opportunities for innovation. Acceptance and trust are additional factors influencing the projects. Therefore, constructive and goal-oriented 'interaction' and communication between the stakeholders on district and project level are key factors for success. It is important to share data and information to guarantee an early integration of important stakeholders, including the public.

Projects in all three areas have the ambition of improved sustainability, although data on the actual impact is limited. The housing projects can be argued to contribute to sustainability in all three areas: environmental, social and economic.

The district heat networks are supposed to reduce environmental impacts compared to current systems, but there was insufficient monitoring information available to prove this. The alternative water management systems all make a contribution to environmental sustainability and can be shown to be economically viable. If successful, projects in all three sectors can strengthen local social structures. Economic sustainability is a necessary condition for the success of projects in all three areas and this requires financial support and resources that are not available through the conventional housing, energy or water services market institutions.

While projects on district and household level are fundamental to a sustainability transition, efforts for up-scaling their impacts (Luederitz et al. 2017) are just as important. The challenges for actors on local to global scale are to learn from different narratives and adapt different perspectives, build unconventional alliances and collaborations to implement innovative, creative and intelligent solutions for a sustainability transition on a larger scale (Luederitz et al. 2017; Wittmayer et al. 2016; Brown et al. 2013).

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