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Wuppertal Institut

*Georg Holtz a,**
Chun Xia-Bauer a
Michaela Roelfes a
Ralf Schüle a
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a Wuppertal Institute for Climate, Environment and Energy, Wuppertal, Germany

* Corresponding author:
Georg Holtz
Wuppertal Institute for Climate, Environment and Energy
Döppersberg 19
42103 Wuppertal
Germany

E-mail: georg.holtz@wupperinst.org
Phone: +49 202 2492 313

Wuppertal Institut

Competences of local and regional urban governance actors to support low-carbon transitions: Development of a framework and its application to a case-study

Georg Holtz*[,a], Chun Xia-Bauer[a], Michaela Roelfes[a], Ralf Schüle[a], Daniel Vallentin[a], Lilia Martens[a]

[a] Wuppertal Institute for Climate, Environment and Energy, Döppersberg 19, 42103 Wuppertal, Germany

*Corresponding author: Georg.Holtz@wupperinst.org

Abstract

Urban areas, being responsible for large shares of global greenhouse gas emissions, are important arenas for achieving global decarbonisation. However, the systemic challenge of decarbonisation requires deep structural changes – transitions – that take place across multiple scales and along entire value chains. We argue in this article that understanding the role of urban areas for global decarbonisation therefore requires consideration of their context and analysis of urban areas' contributions to transitions that extend past the individual urban area. We develop an analytical framework that proposes three principal ways urban areas contribute to low-carbon transitions and ten competences that regional and local governance actors have to support them. We apply this framework to the Cologne metropolitan area in Germany to demonstrate the ability of our framework to relate urban-scale activities to more encompassing low-carbon transitions. The paper concludes with future research possibilities.

Key words: urban transformation; structural change; multi-level perspective; framework; Cologne

1 Introduction

Urban areas are key engines of economic development and account for a disproportionately large share of countries' per capita gross domestic product (GDP) (Hammer et al., 2011; UN-Habitat, 2015; World Bank, 2010). The high level of economic activity in urban areas also produces negative externalities. In particular, cities are responsible for three-quarters of global greenhouse gas (GHG) emissions (IPCC, 2014; World Bank, 2010; Rosenzweig et al., 2010). For this reason, various studies have highlighted the importance of urban areas for mitigating climate change (e.g. Seto et al., 2014; OECD, 2010a). Bulkeley (2010) has examined the history and development of urban climate governance. She concludes that after two decades of policy interventions at the city level, a gap remains between rhetoric and action. Policies are concentrated on those issues in which local co-benefits can result, and there is little evidence of the impacts and effectiveness of such measures in limiting GHG emissions.

At the same time, there is increasing awareness that end-of-pipe solutions and technical innovations alone are not sufficient for addressing persistent, complex and systemic challenges, including the challenge of decarbonisation (OECD, 2015a; EEA, 2015). Instead, deep structural changes in key areas of human activity, including transport, energy, housing, manufacturing and other systems are required (EEA, 2015; OECD, 2015a). McCormick et al. (2013) have pointed out that there are only a few examples of deep structural change towards sustainability in urban areas. They therefore aim to advance knowledge and understanding of multi-dimensional and radical change in urban areas and provide a framework for sustainable urban transformation encompassing urban structures and the main drivers of change.

Referring to Cash et al. (2006) and García-Sánchez and Prado-Lorenzo (2009), McCormick et al. (2013, p. 2) argue that "sustainable urban transformation is not just about local action, but how it 'fits' into multiple scales and levels, and the dynamic relationships that exist." Urban areas are always part of a wider consumption-production system, driving consumption emissions across globalised supply chains (Sudmant and Gouldson, submitted to this special issue). They are embedded in regional, national and global infrastructure systems as well as systems of multi-level governance (Betsill and Bulkeley, 2006; Child Hill and Fujita, 2003). De Oliveira et al. (2013) have argued that the concentration of decisions made at the city level but which have impacts beyond the city itself means that cities play a disproportionately large role in sustainable development.

The discussion so far suggests that structural change is needed for low-carbon development, that urban areas are the most important sites for such structural change, and that urban areas are deeply embedded in broader systems. In this article, we therefore argue that understanding the role of urban areas for low-carbon development requires consideration of their embedding in the aforementioned multifaceted systems and an analytical perspective on structural change that includes, but is not limited to, the urban area. This proposition includes a shift in perspective from focusing on low-carbon development in a particular city to focusing on the urban area's contribution to low-carbon transitions.

For developing such an analytical perspective, we draw on the field of sustainability transitions research (STRN, 2010), which has developed concepts for understanding the dynamics and governance of deep structural changes. "Transition" is a term that is used in many contexts, and transitions in societal systems can happen on a broad range of empirical scales, from societies as a whole (e.g. from rural to industrial society) to changes in single organizations or firms (Geels et al., 2004). Sustainability transitions research focuses on the level of socio-technical systems that fulfil societal functions (e.g., energy, mobility) and that span suppliers, producers, consumers, regulatory agencies and other organisations such as lobbying groups and NGOs. Geels and Schot (2010) define a transition as shift from one socio-technical system to another. Rotmans and Loorbach (2009) define a "transition" with more detail as "a radical, structural change of a societal (sub)system that is the result of a coevolution of economic, cultural, technological, ecological, and institutional developments at different scale levels." Empirical research shows that transitions take place through

interrelated developments at multiple temporal, spatial and administrative scales. They involve interconnected changes along the entire value chain of consumption-production systems (Grin et al., 2010; Markard et al., 2012).

However, understanding of the relevance of space and places for sustainability transitions is in its infancy (Coenen et al., 2012; Hansen and Coenen, 2014; Raven et al., 2012). At this time, there are no widely established concepts that help to understand the contribution of urban areas to global low-carbon transitions. Moreover, the active contribution of urban areas needs to be enacted by local and regional governance actors themselves. The question thus arises by which means governance actors on the local and regional levels can achieve this.

Drawing on a range of literature, this article develops an analytical framework to categorise the different ways governance actors in urban areas can support low-carbon transitions. The framework distinguishes between three principal *contributions* of urban areas to low-carbon transitions and suggests ten *competences* that regional and local governance actors can make use of to support low-carbon transitions. By developing this framework, we address a research gap revealed by McCormick et al. (2013), who identified a need for research on socio-technical transitions focusing on cities. We also answer a call for alternative theoretical perspectives; Bulkeley (2010) claimed that relatively few theoretical approaches have been developed to understand the subject of cities and climate change.

We illustrate the framework using three brief examples from the metropolitan area of Cologne in Germany, each example addressing one *contribution* and referring to a range of *competences*. The application of the framework shows that local and regional governance actors already contribute to low-carbon development in the suggested ways, and that our framework allows scholars and policymakers to relate those activities more clearly to all-encompassing low-carbon transitions. We then address future research needs and summarise our main conclusions.

2 The conceptual background

To develop the analytical framework, we draw on different strands of the literature: first, we employ insights from transition research in general (Geels, 2002; Grin et al., 2010; Markard et al., 2012; Smith et al., 2010) and from studies on the geography of transitions (Coenen et al., 2012; Hansen and Coenen, 2014) and urban transformation in particular (Hodson et al., 2017; Hodson and Marvin, 2010; McCormick et al., 2013). Strategic niche management (Kemp et al., 1998; Schot and Geels, 2008) and transition management (Loorbach, 2007; Loorbach and Rotmans, 2010) are rich sources for an understanding of the possibilities of governance actors to influence transitions. The literature on green growth / the green economy (GGBP, 2014; Lorek and Spangenberg, 2014; Mun S. Ho and Zhongmin Wang, 2012; OECD, 2015b) provides a source for measures that support low-carbon development, in particular where it focuses on green growth in cities (de Oliveira et al., 2013; Fay et al., 2014; Hammer et al., 2011; OECD, 2010b, 2013). This rich body of literature is complemented by insights from regional innovation studies (Asheim et al., 2011;

Doloreux and Parto, 2004) and condensed to understand the role of urban governance in low-carbon transitions.

The following subsections present the key concepts we use. The multi-level perspective (MLP, see Section 2.1) provides the foundation of our analytical framework. It describes how structural change occurs and which sub-processes are crucial to such change. We then focus on the diverse roles urban areas may play in the aforementioned sub-processes (Section 2.2). Finally, we make some general observations on the possibilities of local and regional governance actors to support transitions (Section 2.3).[1]

2.1 Transitions

Innovations that reduce the environmental impact caused by consumption and production activities are essential for ensuring humans' well-being while respecting environmental capacities to provide resources and absorb emissions and waste from human activities. While innovative, environmentally friendly technology was at the centre of research efforts in the 1990s, concerns for low-carbon development and more generally for sustainability have broadened the perspective in innovation studies since then (e.g. Rennings, 2000; Carrillo-Hermosilla et al., 2010). Innovation studies now look at radical change, not only incremental change. Moreover, scholars working in this area have shifted their focus from purely technological solutions to wider production and consumption systems, including behavioural and institutional aspects. Smith et al. (2010) have outlined how several steps of broadening, both in terms of problem-framing and the analytical perspective, have led to the development of the multi-level perspective (MLP) (Rip and Kemp 1998; Geels, 2002; Geels, 2011), which today is a widely adopted framework for conceptualising and analysing transitions through the interaction of three levels: the regime, the niche(s) and the landscape.

The *regime* is the central concept for sustainability transitions research, because it defines the system boundary where a transition takes place. The regime is conceptualised to fulfil a specific societal function, such as the energy supply, the water supply or housing (e.g. Holtz et al., 2008; Van der Brugge, 2009; De Haan and Rotmans, 2011). It comprises various interdependent components, including technologies, infrastructure, institutions and actors that are involved in the implementation of the societal function. A variety of highly institutionalised processes tend to perpetuate the existing system: the knowledge, capabilities and employment of various actors relevant to the maintenance of existing systems; the technical infrastructure and institutions (which have developed over time to service those systems); economies of scale and the markets of incumbent systems; the social significance of these systems and their links to political power; the mutually reliant clusters of technologies used by these systems; and the everyday practices and lifestyle values that have come to rely on these systems (STRN, 2010).

[1] We provide a more detailed discussion of the specific competences of local and regional governance actors in Section 3.2.

The interconnected and self-stabilising character of the regime implies that fundamental change only happens through innovative configurations of market and user preferences, cultural and symbolic meaning, infrastructure and maintenance networks and industry and production networks, as well as regulations and government policy that have emerged around radical innovations and that constitute alternative systems for fulfilling a societal function. The MLP conceptualises the development of such configurations to happen at the *niche* level in protected spaces that are not subject to pressure of normal markets. In these niches, radically innovative configurations emerge through processes of network building, learning, the development of standards and business models, institutionalisation and technological advancement (Schot and Geels, 2008).

Finally, the *landscape* level includes slow-changing, pervasive trends (such as demographic shifts, climate change) as well as more short-term shocks such as disasters (e.g. Fukushima) and other major events (e.g. Brexit) that affect the regime and niches.

According to the MLP, transitions come about if both a) the regime is under pressure from landscape developments, and b) niches exist which put pressure on the regime to provide alternative solutions. Transitions may occur along various pathways of landscape-regime-niche interactions (Geels and Schot, 2007), but the constitutive result of a transition is the substitution of a regime or a fundamentally changed regime. It is important to note that the MLP "levels" are not geographical in their nature, such as urban areas; instead, they are concepts of the maturity and stability of socio-technical configurations (niches, regime) and their embedding in deep structures and trends (the landscape).

The MLP considers transition dynamics to be strongly shaped by the logics rooted in the nature of particular regimes that fulfil societal functions, and consequently the analytical focus usually rests on a particular sector, such as transport or energy. Furthermore, the MLP puts significant emphasis on lock-in factors and the role of interconnected system elements – configurations – for the dynamics of system innovation.

2.2 The relevance of urban areas for low-carbon transitions

Organisations at municipal and regional levels deliver various services such as energy supply, transport or housing. Systems that fulfil these functions at the city and regional scale contain configurations of well-articulated components (e.g. local infrastructures, institutions, culture, actor networks – including governance networks), which create inertia and stability (Hodson and Marvin, 2010). These components and their configuration thus reflect the features of a prevailing regime. While an all-encompassing transition occurs, part of this process is that these local and regional configurations undergo change, too. As such, the transformation of the respective urban sector is a part of the broader regime change that is achieved through manifold processes of structural change at various levels and in different locations, including changes to organisations of local and regional scope. These

changes of local and regional scope have to be enacted by local and regional actors (Geels et al., 2016; Quitzau et al., 2013).

On the other hand, urban areas also provide spaces for radical innovations which, by definition, face a significant mismatch with components of the prevailing regime and whose developments are associated with considerable uncertainties and risks (Jacobsson and Bergek, 2011). Urban areas are home to industrial clusters, centres of excellence, spaces for social innovation, and many other types of innovation spaces. Specific local conditions – e.g. natural endowments, specific local institutions or particular actor constellations – may provide favourable conditions for the development of radical innovations, their deployment and testing, and the establishment of corresponding actor networks and resources to support those innovations. By doing so, urban areas can demonstrate the feasibility of particular configurations, thereby giving them credibility (Spaeth and Rohracher, 2012). In some cases, urban areas had developed pioneering policies, for example, in the fields of climate change and eco-innovation, well before national-level policies were formulated (European Commission, 2012). Urban areas can thus provide the space and the conditions for niche experiments that contribute to the emergence of a global niche (Schot and Geels, 2008).

A large number and diverse range of innovations compete, coexist and complement each other in the geographical context of urban areas (Hodson et al., 2017). Furthermore, interactions and co-evolutionary processes across sectors induced by more encompassing developments, such as shifts in values towards environmental awareness, economy-wide policies and emerging niches at the intersection of multiple sectors,[2] pose challenges to coordinating developments across sectors and finding suitable solutions. Therefore, urban transformation is a multi-dimensional design problem that requires integrated and creative solutions (McCormick et al., 2013). Considering the interconnectedness of sectors at the urban scale, as well as the smaller scale regarding the challenge of implementation, designing effective multi-sector solutions can actually be more manageable at this level than at the national level (GGBP, 2014). Solutions can be designed that take local conditions and priorities into consideration. Indeed, evidence shows that city and regional actors can better design successful measures for reducing the environmental impacts of local economic development activities due to the proximity of environmental impacts and local specific resources, e.g. the knowledge of local innovation systems, the social-political situation, environmental challenges, and social capital (Hansen and Coenen, 2014). Moreover, the commitment of civil society actors is usually easier to engage at the local scale (Spaeth and Rohracher, 2012). Urban areas are thus arenas in which the interaction of multiple transitions is particularly prominent, and in which the range of developments can be arranged and integrated most effectively.

[2] For example, biomass energy links agriculture to energy, and electric transport links transport with the energy system.

2.3 Possibilities of local and regional governance actors to support low-carbon transitions

We use the term "governance actors" to loosely capture a broad range of actors that are organised beyond spontaneous meetings and that claim to work for the general interest of the public (e.g. politicians, administration, foundations) or represent stakeholder groups (e.g. NGOs, associations). Furthermore, we combine local (municipality) and regional (e.g. district) level actors, because we take a functional approach[3] to delineating the boundaries of urban areas and therefore multiple administrative scales may be involved in the governance of an urban area. Administrative scales are specific to governance structures, and our goal is to create a framework that is applicable to different contexts; for this reason, we apply such a broad definition of the term "governance actor". Hence, when applied to different contexts, the competences proposed in Section 3.2 need to be seen in light of the specific case. For sake of clarity, it is important to note that in the multi-level perspective and contrary to some other conceptualisations, governance actors are not characterised as belonging to either the regime or niche simply because of their role or position (e.g. an elected city councillor is not necessarily by definition a regime actor).

A policy framework for transitions should include measures that support niche creation and the upscaling of low-carbon solutions, but also measures for the destabilisation of the dominant regime (Kivimaa and Kern, 2016). Examples of the former are R&D funding schemes, innovation platforms and tax exemptions. Examples of the latter include cutting subsidies, introducing environmental regulations (e.g. pollution taxes), or banning certain products and services. It has to be noted, however, that the powers of local and regional actors are strongly dependent on and specific to the respective multi-level governance structure and culture to which they belong.[4] In many cases, municipalities have limited powers and responsibilities in sectors relevant for low-carbon development (Bulkeley, 2010). Nonetheless, as explored in Section 3.2, local and regional governance actors have several competences to support low-carbon transitions related to their formal powers of planning and to their "soft power", including local knowledge and its integration in governance networks. At the regional level, the low-carbon transition requires overcoming administrative boundaries of municipalities and integrating their development needs regarding land use, housing and transport (Tepecik Diş et al., 2014).

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[3] Various methods exist to establish the boundaries of a city or urban area. We follow the approach of functional boundaries, which delineates areas according to connections or interactions between areas owing to economic activity or commuting, for instance.

[4] For example, in Europe, policymakers at the local level typically have limited options to use coercive policies to influence production and consumption decisions taken by local actors. On the other hand, culture allows for and even requires the strong participation of stakeholders and the public in (local) policymaking. These aspects may be different in other areas of the world.

3 The analytical framework

Based on the conceptual background explained above, we can identify three broad *contributions* of urban areas for transitions to low-carbon development, and ten *competences* that local and regional governance actors have to support those contributions. Figure 1 summarises which competences are most important for which contribution.

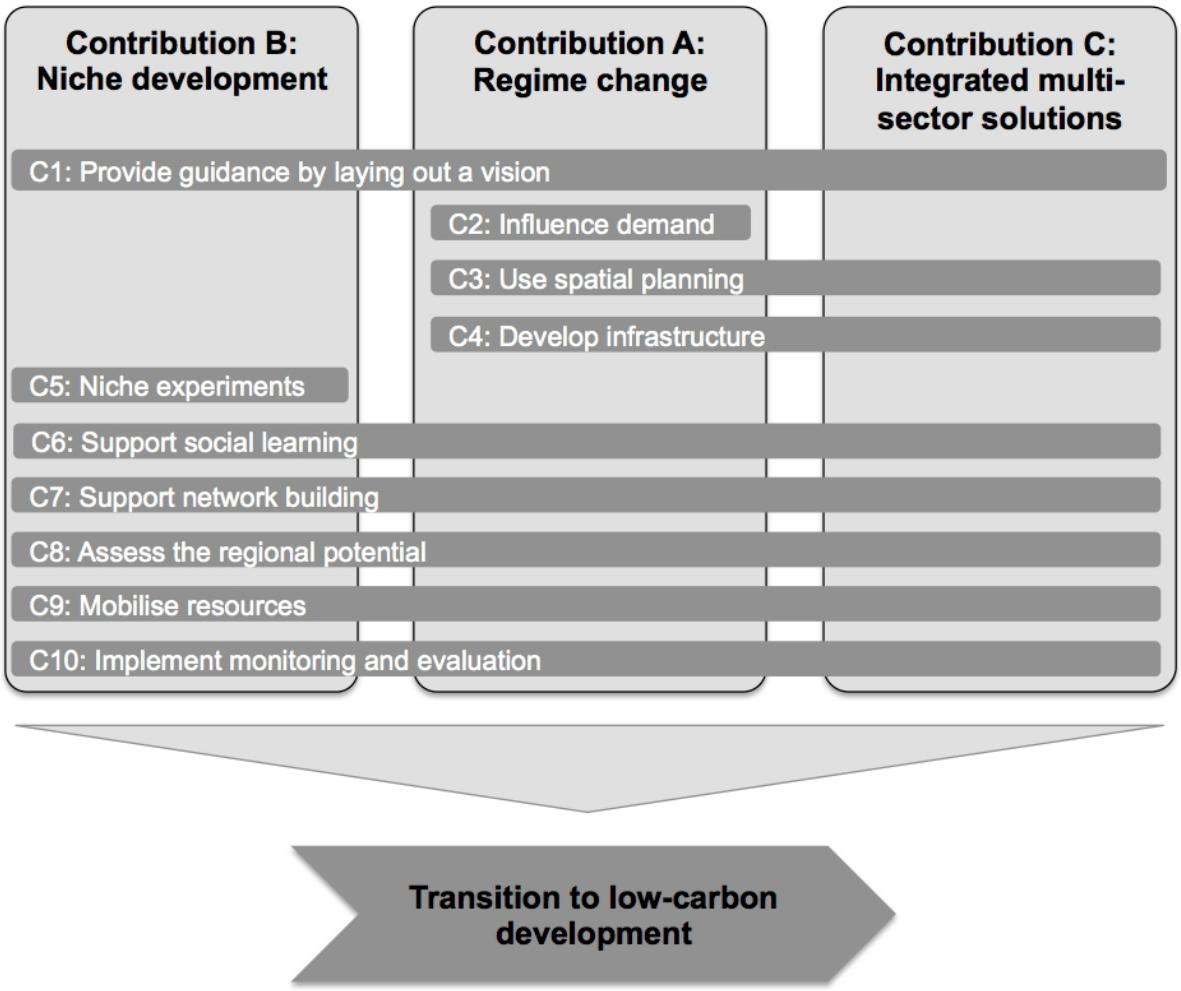

Figure 1: Three contributions of urban areas to transitions to low-carbon development and ten competences (C1-C10) of local and regional governance actors that support these contributions.

3.1 Contributions

A. *Regime change*: urban areas are locations in which regime change is accomplished through changes to infrastructure, institutions, production and consumer behaviour within the boundaries of the urban area. Actors in urban areas enact those changes and can thus support regime change locally, e.g. by changing their behaviour and local regulations, and by adopting and implementing market-ready renewable energy technologies or low-carbon transport measures.
B. *Niche development*: urban areas provide spaces and conditions for experiments using radically innovative configurations that deviate from the

prevailing (inter)national regime and contribute to the development of those innovative configurations to market-readiness.

C. *Integrated multi-sector solutions*: urban areas are locations in which developments across sectors are coordinated; multiple developments are integrated together, taking local conditions into consideration. As such, urban areas are important sites for the mutual alignment and integration of multiple (sectoral) transitions.

3.2 Governance actors' competences to support low-carbon transitions

Competence 1: Provide guidance by laying out a vision

Defining clear objectives and a vision of the desired future involves specifying the general idea of low-carbon development for a particular urban area and is usually accompanied by more specific short-term and medium-term goals (GGBP, 2014). Clear objectives and vision statements have an effect on both the niche and the regime level, by shaping the expectations of actors and by providing guidance for their actions. For niche actors, clear expectations provide a cognitive frame for and a direction to learning processes, enabling them to focus attention and resources, and legitimise the (continued) protection and nurturing of niches (Schot and Geels, 2008; Raven, 2007). A vision statement can thereby align expectations for a wide range of heterogeneous actors who are characterised by large differences in cognitive and social interests, but whose interaction is key for niche development (Bergek et al., 2008).

Shared visions and strategies for low-carbon development are equally important for destabilising the regime and facilitating regime change (Hansen and Coenen, 2014; Hodson and Marvin, 2010), e.g. by providing guidance for spatial planning, infrastructure development, firms' capital investments and innovation activities, and consumer behaviour (see C2-C4)[5].

Competence 2: Influence demand

Cities and regions are sources of demand for goods and services, in terms of both intermediate consumption by local business and final consumption by citizens and public bodies. Depending on the kind of products and services they demand, they support the respective value chains, including the economic activities and environmental pressures related to these. As such, cities and regions can support regime change and foster low-carbon development by articulating demand correspondingly. Policymakers can influence demand in urban areas with a range of policy measures, including price, regulatory, fiscal and information/education measures that influence the decision-making processes of users and investors to adopt low-carbon products and services (Camagni et al., 1998). In addition to supporting low-carbon solutions, measures that destabilise the dominant regime can be applied (Kivimaa and Kern, 2016). Examples of the latter include cutting

[5] Here and in the following, we abbreviate "Competence N" with "CN".

subsidies, introducing environmental regulations (e.g. pollution taxes) and banning certain products and services.

Competence 3: Use spatial planning

Spatial planning structures space and defines its usage for different purposes, such as residential areas, commercial areas, infrastructure and nature. Spatial planning lays the foundation for infrastructure development (see below) and for the viability of socio-technical configurations, i.e. the planned spatial structure may support the continuation of the regime or the upscaling of niches. For example, low-carbon solutions such as car-free neighbourhoods and district heating require specific spatial planning. Furthermore, the urban form has been identified as a critical factor influencing energy demand and GHG emissions (Holden and Norland, 2005; Leck, 2006). A compact urban form, for example, is very likely to decrease GHG emissions due to shorter travel distances and on average smaller dwellings (Holden and Norland, 2005; Lee and Erickson, 2014). A corresponding planning strategy for compact urban development has the largest potential in the rapidly growing cities of the emerging economies in the Global South.

Competence 4: Develop infrastructure

Energy consumption is closely related to the type of infrastructure implemented in urban areas, such as transport infrastructure (Rickwood et al., 2008) and district heating (Rezaie and Rosen, 2012). For this reason, infrastructure design is key to reducing resource consumption and emissions resulting from local demand. Governments may renovate or expand urban infrastructures for established low-carbon solutions, such as public transport and heat networks, or they may implement infrastructure for upscaling innovative niches, such as battery recharging infrastructure for electric vehicles, or smart grids that support higher shares of decentralised renewable energy generation (Bolton and Foxon, 2015). Changes to infrastructure can also be used to destabilise the regime; for example, roads can be closed to cars and restricted to cyclists and pedestrians only.

Competence 5: Provide space for niche experiments

The development of radical innovations in niches calls for a "learning-through-experimentation" approach to explore technical aspects and design specifications of these innovations, to develop a configuration that works around these innovations, and to assess their effects on society, the economy and the environment (Schot and Geels, 2008; Bergek et al., 2008). Governance actors may have the power to deliberately and strategically create protection for such experiments, either by directly leading pilot projects themselves (sometimes with support from or in cooperation with actors from the state or federal level) or by making spaces available for investors and end users, and providing them with preferable conditions. This may involve spatial planning (C3) and infrastructure development (C4), but occurs more on an *ad hoc* basis.

Competence 6: Support social learning

"Social learning" encompasses learning in a social context among multiple actors with various interests and values, in which they are engaged in "double-loop learning". Double-loop learning occurs when actors reflect on their own frames of reference and recognise other legitimate frames of reference as well as their interdependencies (Pahl-Wostl et al., 2008). Social learning is relevant for low-carbon development in at least two ways. First, social learning is important for the articulation of a joint vision and the development of shared expectations (see Competence 1). Second, regime change in the urban area involves finding creative solutions tailored to local conditions that require collaboration between diverse stakeholders – particularly if developments in different societal sectors need to be mediated and aligned. To support social learning, governance actors can provide leadership and vision-related capabilities, and can facilitate constructive dialogue among key actors (Hamann and April, 2013).

Competence 7: Support network building

Niche development requires the establishment of new actor networks (Kemp et al., 1998; Schot and Geels, 2008) that bring together different but complementary pieces of knowledge from different organisations, and thus facilitate knowledge spill-over for innovations. When niches have matured and start to transform the regime, networking among niche actors and major regime actors becomes important for the integration of niche elements into a transformed, new regime. Developing integrated multi-sector solutions may also require connecting actors that have experienced only little interaction in the past. Governance actors can support the initiation and development of such networks and the intermediary organisations that facilitate these networks. Khan (2013) has investigated the role of network governance in low-carbon transitions and has concluded that network governance mobilises actors from different backgrounds and sectors for low-carbon action and has the potential to create and nurture niche developments, particularly if win-win solutions for the relevant actors are identified. However, Khan also warns that the elitist character of network governance runs the risk of weak accountability and democratic control and may reinforce existing patterns and structures.

Competence 8: Assess the regional potential

To facilitate transitions to low-carbon development, it is essential to understand the local potential in terms of the endowment of natural resources as well as technological and industrial specifics (e.g. green firms and innovation assets in the green sector), the patterns of various flows through the city (such as energy, traffic), and the existing actor networks that can be mobilised (Hansen and Coenen, 2014; Doloreux and Parto, 2004). These features make local transitions differ from each other. A sound understanding of the regional potential provides a basis for all of the above competences. Governance actors at the city and regional scale can develop and provide such knowledge through collaboration with, for example, research institutes and/or think tanks.

Competence 9: Mobilise resources

Mobilising a range of resources, including human capital, financial capital and social capital, is a general competence to support all other competences (Schot and Geels, 2008; Smith and Raven, 2012). Policymakers can collaborate with regional institutions and private sector actors to provide training and develop education programmes on innovation and the employment of low-carbon products and services (Hammer et al., 2011). In addition, governance actors can draw significant financial resources from higher administrative levels (including on both the national and the supranational level, e.g. the EU Structural Funds, climate financing) or other funding sources (e.g. private foundations, support programmes among networks of cities).

Competence 10: Implement monitoring and evaluation

It is important to monitor and evaluate the urban area's contribution to low-carbon transitions in order to learn about the system and to adjust future activities within the urban area, taking into consideration developments within as well as beyond the urban area. To monitor regime change and the growth of niches, data should be collected on the following topics: industry structure, technologies available and in use, market shares, consumption levels and infrastructure provision. Furthermore, the impact of these changes in terms of GHG emissions and energy consumption should be measured. Monitoring and evaluation of long-term transitions therefore requires longitudinal data collected over many years. Such data may be available from data collected for the Millennium Development Goals and Sustainable Development Indicators, for example (GGBP, 2014). Data availability on the regional and local level might be scarcer than on the national level, however. To collect data on a regular basis, it is necessary to have a robust institutional arrangement, including the allocation of corresponding resources.

However, the evaluation of transitions needs to go beyond the evaluation of changes of market-related and technology-related indicators to include the overall vision and interim objectives, problem definition, and lessons learnt from niche experiments, as well as an evaluation of any behavioural and institutional changes. This requires monitoring the status of radical innovations at the niche level that may not yet have market relevance, the status of changing institutions and social practices, and the status of evolving discourses and actor networks (Loorbach, 2007). To our knowledge, the development of (composite) indicators that cover this diversity of aspects of relevance for transitions is an area for future research.

4 Contributions to low-carbon transitions in the metropolitan area of Cologne

The appropriateness of the framework was investigated in an exploratory sequence of expert interviews conducted in the metropolitan area of Cologne, including an adjacent area known for lignite mining (the *Rheinisches Revier*). Both the city of Cologne and the Rheinisches Revier are located within the governmental district of Cologne in the southwest part of the Federal State of North Rhine-Westphalia.

According to official statistics from 2015[6], this district was home to more than 4.4 million people and population projections forecast further growth. The district is already one of the most densely populated areas in Germany. Due to its central location in Europe, the region plays an important role in economic production, traffic, tourism, cultural exchange, science and innovation (Region Köln/Bonn e.V., 2016). The regional economy is outstandingly diversified, including enterprises of all sizes and sectors. These include firms in the chemical, metal, automobile and food industries that are located along the Rhine River (Region Köln/Bonn e.V., 2015).

The city of Cologne is one of Germany's fastest growing metropolises; the city expects to grow by 20% by 2040, which will create high pressure on housing not only in the city itself but also in the surrounding municipalities (Stadt Köln, 2016a). At the same time, the city of Cologne is already densely built and the government has struggled to find areas that can be converted for housing. The resulting competition over land use will intensify over the next decades (Region Köln/Bonn e.V., 2015) and will pose a threat to strategic and long-term planning for low-carbon development. Cologne is also one of the most important transport hubs in the western part of Germany and among the most important hubs for the road transport sector in Europe (Stadt Köln, 2014a). Because of the Rhine River, Cologne is also part of Europe's important inland waterway transport system and currently has two cargo ports that are very important for the chemical industry and the regional economy in general (Lucas and Wilts, 2007). Furthermore, Cologne is central to Europe's rail transport system.

Just a few miles west of Cologne is one of Europe's largest lignite mining areas, with exploitable reserves of roughly 35 billion tonnes (Gerbaulet et al., 2012). Located between the cities of Aachen to the west, Düsseldorf to the north, Bonn to the south and, as indicated, Cologne to the west, the Rheinisches Revier produces roughly 100 million tonnes of raw lignite per year, most of which is converted into electricity in nearby power plants. Due to the cheap and stable supply of power that comes from close proximity to coal-fired power stations, energy-intensive industry in particular has settled in this area (e.g. chemicals, aluminium). As a result, this otherwise rather rural and suburban area is characterised by an integrated economy based on lignite, and provides a considerable share of Germany's electricity. However, the region is faced with a planned phase-out of lignite-related activities in the coming decade(s) as a result of the German *Energiewende* and therefore has been preparing for structural change (IRR, 2013). As such, the metropolitan area of Cologne (the city itself and the surrounding counties) has come under constant and increasing pressures of population growth, land use demand and impending structural change.

In 12 semi-structured expert interviews with local and regional stakeholders, including representatives from municipal and regional administrations and politics, from business and industry, from chambers of industry and commerce, and from civil society, we investigated the strategies and policy instruments used to foster low-carbon development. The interview results were complemented by a document

[6] See https://www.it.nrw.de/statistik/a/daten/bevoelkerungszahlen_zensus/zensus_rp3_dez15.html

analysis of existing policy strategies in the region. Based on this empirical work, we use the following examples from the metropolitan area of Cologne to report on the three different *contributions* to low-carbon transitions proposed in the framework presented in Section 3, as well as the *competences* of local and regional governance actors to support those contributions.

4.1 A solar park as a symbol of regime change (Contribution 1)

The German *Energiewende* has been developing for some time and has induced numerous changes; the metropolitan area of Cologne has not been immune to this. Governance actors at the local and regional level are important actors in implementing this transition. For example, they have developed integrated climate protection plans on the city level (e.g. Stadt Köln, 2012) that provide guidance for future action (C1), as well as transit concepts that provide guidance for spatial planning (C3) and infrastructure development (C4) (e.g. Stadt Köln, 2014a). On the regional level, actors such as Köln-Bonn e.V. have facilitated network building (C7) and have supported peer-to-peer and social learning (C6) (Region Köln/Bonn e.V., 2015).

Governance actors are, however, also involved in the *de facto* implementation of projects. A prime example is the case of the Solar Park Inden: this park was built in 2011 in the municipality of Inden, which is located in the Rheinisches Revier and is part of the administrative county of Düren (Kreis Düren). It includes 16,236 solar modules that provide a maximum power output of 3.9 MW (peak). The park has been erected on a 10 hectare area of a former household waste landfill. At the time of its construction, the park was the biggest of its kind in North Rhine-Westphalia. In the immediate vicinity of one the five coal-fired power plants ("Weisweiler") of the Rheinisches Revier, the solar park is perceived as a symbol of change (C6). This perception has been supported through the public announcement of the project and a celebration of the opening of the park to which the public was invited.

The head of the county of Düren initially came up with the idea for the solar park based on his knowledge of the local situation (C8). The park was then planned and constructed under a management team led by the county of Düren. Sparkasse Düren (a regional bank) was involved in financing, and F&S Solar, a firm located in a neighbouring county that is active worldwide as a solar park specialist, was involved in the construction of the park, and is a partial owner of the complex (approx. 40%). RURENERGIE GmbH was established to oversee operations of the Solar Park. Shareholders of RURENERGIE GmbH are the local energy utility (Stadtwerke Düren), Kreis Düren and Sparkasse Düren. The latter also established a public fund through which citizens could contribute to the funding of the park (C9) and gain from the revenues. The solar park has been a "starting shot" for further innovation activities in area. Since then, RURENERGIE GmbH has become an active player in the region, dedicated to the implementation of renewable energy systems. Solar modules have been installed on many roofs of public buildings and schools in the county, and RURENERGIE GmbH has also been involved in a regional wind park project since 2013.

4.2 Resource-efficient and low-carbon buildings as a developing niche (Contribution 2)

The metropolitan region of Cologne is home to many universities, universities of applied sciences and other applied research institutes. Most of them are heavily involved in the development of technological innovation. A broad range of business and industry partners, including RWE/Innogy (a major energy provider), are located in the region and involved in research collaboration on, for example, fuel cell and hydrogen-based transport. Such research collaborations are often part of larger networks at the state or national level.[7] However, successful collaborations between business and academia always require a certain structural embedding that enables and supports those collaborations and the testing of innovative ideas; this is where local and regional governance actors come into play. Urban areas and governance actors on local and regional levels play a decisive role when it comes to providing the necessary local (physical and institutional) infrastructure for such innovative ideas as well as real-world experiments and trials. For example, Cologne's regional transport service provider (Regionalverkehr Köln GmbH[8]) currently runs four hydrogen buses as part of their regular fleet to test and demonstrate the feasibility of hydrogen-fuelled transit and is attempting to completely replace its otherwise fossil-based fleet one bus at a time.

One prime example of an innovative idea that has developed in a niche, supported by local governance actors, is the area of "resource-efficient and low-carbon buildings" that go far beyond general standards. These projects focus on the complete value chain of a building, looking not only at the energy consumption and the emissions of a building in current use but also at the complete value chain of construction, dismantling and the disposal or reuse of materials.

In one group of projects, two neighbourhoods[9] (covering 2.5 ha and 3.7 ha and providing space for 34 and 60 properties, respectively) have been planned to include buildings whose ecological backpack and carbon emissions would be half of current German standards,[10] assuming an operational lifetime of 50 years (known as a "Factor 2" building). Most of the properties have already been sold and the first buildings are currently under construction. In addition, the developers are also currently constructing one building for demonstrative purposes whose ecological footprint will be a quarter of the current German standards (i.e. a "Factor 4" building). In order to support the replication and diffusion of Factor 2 buildings, transferable tools have been developed, and business companies will be trained to put similar projects into practice (C9). Moreover, two additional neighbourhoods are already under consideration as follow-up projects.

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[7] For example, see http://www.energieagentur.nrw/english/the_energyagency.nrw

[8] See http://www.rvk.de/startseite.html

[9] These are the Inden Seeviertel in Inden (http://www.inden-seeviertel.de/info.html) and the Neue Höfe Dürwiß in Eschweiler-Dürwiß (http://www.neue-hoefe-duerwiss.de/)

[10] i.e. KfW55

The project consortium of the initial two projects consisted of public authorities and a private foundation, as well as RWE, which is not only the dominant energy provider in the area, but also the owner of many properties in the region. The initial developments were funded by the partners' resources, above all providing the manpower for spatial and development planning (C3). In both municipalities, town hall meetings were conducted to explain the energy concept to the local public, as well as to receive feedback and answer questions. This was particularly important with respect to clearing up initial misunderstandings and explaining rumours; afterwards, the response was very positive, and the demand for properties was unexpectedly high. The project was thus able to provide a compelling vision (C1) and support social learning (C6). Furthermore, Factor-X buildings and neighbourhoods are niche experiments that the project provided space for (C5).

A closely related project has focused in particular on the recycling of building materials in the spirit of a circular economy, investigating additional ways to reuse material from dismantled buildings for structures above ground, instead of only using it for underground engineering (particularly streets). The project has been led by Innovationsregion Rheinisches Revier GmbH,[11] a broad consortium of local and regional governance actors from the area, including the governments of six counties, among others. The project has two main goals: the first is to create a dynamic network of partners (about 25) from politics, administration, academia and business (C7) culminating in the development of a joint thesis paper to be presented to policymakers on the federal state and national levels (C1). The second goal is to identify and persuade investors about a pilot location at which innovative recycling practices will be implemented for the first time (C5). The project is funded in large part by EU funding that the project initiators have successfully secured (C9).

In addition to the aforementioned contributions to fostering innovative approaches, these projects also contribute to the genesis of a perspective that not only tackles wide-raging problems, but also challenges the dominant regime: current German legislation (Energieeinsparverordnung – EnEV) at this time neglects the pre-use and post-use phases of a building's life cycle. However, there is a great deal of potential with regards to resource efficiency and emissions reductions in these two phases and, therefore, the current regulations require reconsideration, as the interviewees argue.

4.3 The competition for space requires integrated, multi-sector solutions (Contribution 3)

For our third case, we look more closely at the city of Cologne and its directly neighbouring municipalities. Against the backdrop of a rapidly growing city – growing in terms of population, economic activity and traffic volume – the city administration faces challenges on multiple fronts. There has been an ongoing influx of new residents and, according to population forecasts, this will multiply in the years to come. The city of Cologne is densely built; there are virtually no areas left to rezone for other purposes and, as a result, the competition over land use is increasingly

[11] For additional information, see http://rheinisches-revier.de/irr/

intense. Although the long and largely interconnected "green belts" of the city are highly valued by its citizens, the population growth has increased the pressure to convert parts of those green areas into residential areas. Furthermore, the city lacks the space to even accommodate the business headquarters of larger companies, not to mention production or logistics centres. When asked about the status quo in terms of strategic policy action regarding sustainable and green space planning, our interviewees unanimously criticised the non-existence of an integrated concept for city development. It seems that a clear vision (C1) for city development is lacking up to this point.[12]

The influx of new inhabitants also goes hand in hand with more and more people moving to surrounding municipalities, because of high costs of rent in particular and the lack of living space in general (Stadt Köln, 2016b). As a result, those trying to avoid the city nevertheless transfer the housing pressures to Cologne's suburbs and neighbouring cities, and increase the strain on the region's transport infrastructure. Our interviewees confirmed our hypothesis, arguing that an inter-municipal or even regional approach to land use management (C3) would be necessary to tackle the challenges of rapid growth, pointing at both institutional and cultural barriers to such a cooperative approach. Currently, an agglomeration concept for the overall region of Cologne and Bonn is being developed as a professional contribution to the more general regional development plan. While the attempt was welcomed by most of the interviewees, some nevertheless simultaneously condemned it as toothless.

The metropolitan area of Cologne, as a hub in various European transport networks, struggles with high transport volumes as well; this puts significant stress on regional infrastructure. So far, Cologne's city government has reacted by commissioning a new "Urban Development Concept of Logistics"; the first part, on "Analysis, Trends and Guidelines" (C8), was adopted in 2016 (Stadt Köln, 2015). Our interviewees nevertheless expect that huge investments will be necessary to come to terms with the continually growing transport volume. Others see the proposed expansion of the port of Godorf (in the City's south) as a potential solution to ease pressure on overland transport. These plans, however, have resulted in heated debates since the 1990s, and official citizen participation in 2011 failed to meet the required participation rate and was, therefore, deemed inconclusive. In actual fact, the case of the port is itself a prime example of conflicting land use needs and the difficulties in managing those conflicts.

In sum, the rapid growth of Cologne has created an urgent need for integrative solutions that account for and balance demands for housing, transport, commercial areas and recreation (green areas). How these different demands will be met is crucial for future dynamics and CO_2 emissions in these sectors. For example, the space dedicated to housing – and related to this, the size of dwellings – influences the energy demand per inhabitant. Another example is the transport sector, for which

[12] In the interest of full disclosure, it is necessary to mention that the city of Cologne is currently in the process of developing a comprehensive strategy for the future development of the city. However, as the process is at its very beginning, it would be presumptuous to speculate about outcomes.

different solutions to meet the increased transport demand of commuters – ranging from the expansion of the road network to the extension of public transport and dedicated bicycle paths and lanes – supports different regimes and niches. Spatial planning (C3) and infrastructure development (C4) are key competences for the implementation of any solution. Solutions furthermore need to be developed based on a sound assessment of the regional potential (C8). However, a clear vision to guide future developments (C1) still seems to be lacking. Institutional and cultural barriers to cooperative approaches across municipal boundaries are a major challenge for developing such a vision and for developing integrated multi-sector solutions that correspond to the inherent interdependency of municipalities.

5 Discussion

The cases described above show that the metropolitan area of Cologne contributes to a transition to low-carbon transitions by manifesting *regime change* and providing space for *niche development*. Furthermore, the development of *integrated multi-sector solutions* tailored to the local situation of rapid population growth in Cologne is an urgently needed contribution by local and regional governance actors. The case studies furthermore confirm that local and regional governance actors have a range of competences to foster those contributions, and the set of competences suggested in Section 3.4 is well reflected in the examples. An exception to this was monitoring and evaluation of the transition (C10), which did not appear in the examples. We expect that this lack of monitoring and evaluation activities is, in part, the result of the complexity and the cross-sectoral nature of sustainability transitions, which cannot be monitored and evaluated using established statistical approaches and quantitative data alone. Further research is needed to test the appropriateness of the framework to apply it in different multi-level governance structures and cultural contexts.

By building on the multi-level perspective, the framework presented in this article provides a broad perspective on structural change, and would be able to integrate a wide range of work on different aspects of urban transitions and local and regional governance actors' competences to support them. By providing such an integrative perspective, the framework supports actors to "think outside the box"– the "box" being particular (economic or policy) sectors, segregated administrative levels or spaces, and the corresponding mental silos within which the actors operate. As such, the framework potentially could support the design of innovative policy. In particular, it points towards niche development as an important contribution by urban areas to transitions towards low-carbon development. Although the related activities may not have a large impact on quantitative indicators used for measuring low-carbon development, they are of major importance for the required structural changes.

The framework presented here is different from most of the literature on cities and climate change (e.g. Bulkeley, 2010; OECD, 2010a) in its explicit focus on structural change. In that, it is similar to the framework for sustainable urban transformation developed by McCormick et al. (2013), which identifies three main drivers of change (governance and planning, innovation and competitiveness, and lifestyle and consumption) and four urban structures (resource management and climate

mitigation and adaptation, transport and accessibility, buildings, and the spatial environment and public space). Compared to the work of McCormick et al. (2013), who have developed their framework in an inductive way based on the contributions to their special issue, the framework presented in this article was developed more deductively, starting from the conceptualisation of structural change in the multi-level perspective. As a result, it does not name crucial sectors or drivers for urban transformation, but instead relates a wide variety of activities on the urban scale to transition dynamics and the processes of niche building, upscaling and regime change. By doing so, it adds a more encompassing perspective on the role of local and regional governance actors in contributing to structural change. While our framework develops this into some sort of extensive "toolbox" of competences that local and regional governance actors have, within the scope of this article we were only able to briefly tap into issues that hamper the effective use of these competences in practice. Hodson and Marvin (2010) have discussed the subtle issues of the relationship between socio-technical regimes and cities in greater depth, particularly focusing on the responsibilities of urban governance networks and their capacities and capabilities to act on regime structures. Bulkeley (2010) has reported on issues of institutional capacity including multi-level governance structures and the problem of "fit", as well as issues of the political economy of urban climate governance that hamper effective low-carbon action. Hodson et al. (2017) have argued that to understand urban transitions, it is most important to comprehend how multiple innovations are experimented with, combined and reconfigured in existing urban contexts, and how such processes are governed. They argue that material relationships between infrastructure or systems that are currently undergoing an embedding process on the one hand, and wider pre-existing urban infrastructure, pre-existing and newly emerging governance networks, and multiple conceptions of sustainability on the other, collectively lead to high variability of urban transitions on the ground. There is therefore a great deal of room for future work to more thoroughly elaborate on the interdependencies between different competences of governance actors included in the framework presented here, as well as their dependence on and interaction with the broader value chains, infrastructure and multi-level governance systems in which the urban area is embedded.

Another issue left for future work is to investigate whether – and if so, under which circumstances – urban governance actors would be willing to exercise the competences identified above. The framework deliberately shifts the perspective from a focus on low-carbon development (including transformative change) within the boundaries of a city to the contribution of urban areas to transitions that include, but are not limited to, the urban area. Given this shift in perspective, the suggested contributions of urban areas include measures that may not pay off (immediately) for actors within the urban area itself. Examples of such measures are a shift in demand towards (more expensive) low-carbon products, even though the reduced carbon emissions during production may be accounted for in different areas of the world. Another example is the nurturing of niches whose (future) economic benefit is not obvious, as is often the case for social innovations. The existence of city networks dedicated to low-carbon development, such as the C40 Cities Climate Leadership

Group and the Cities for Climate Protection (CCP) network, shows that a global perspective of a problem such as climate change may well attract the attention of local actors. Research, however, also shows that effective municipal action requires additional enabling factors, for example a possibility to achieve local co-benefits (e.g. improved air quality) (Bulkeley, 2010).

Finally, one crucial task for the future is to make the framework operational and useful for practitioners. This means addressing questions such as the integration of the long-term perspective on transition into the everyday activities of governance actors, who are often concerned with more short-term needs, responding to these with limited resources.

6 Conclusions

We argued in this article that the systemic challenge of decarbonisation requires transitions that occur across multiple scales and along entire value chains, and that understanding the role of urban areas for low-carbon development therefore requires an understanding of the possibilities of urban areas to contribute to more all-encompassing transitions. We therefore proposed an analytical framework that identified three *contributions* of urban areas to foster low-carbon transitions: (i) regime change, (ii) niche development and (iii) integrated multi-sector solutions. We furthermore determined ten *competences* of local and regional governance actors to support these various contributions: (1) provide guidance by laying out a vision, (2) influence demand, (3) use spatial planning, (4) develop infrastructure, (5) provide space for niche experiments, (6) support social learning, (7) support network building, (8) assess the regional potential, (9) mobilise resources, and (10) implement monitoring and evaluation. The framework presented is distinct from previous work in its explicit focus on structural change, building on established concepts of transitions research for analysing such structural change. The application of this framework to three examples from the metropolitan area of Cologne illustrates that local and regional governance actors have and already make use of a range of competences to support low-carbon transitions. Future research is needed to test the framework in different contexts, to identify the requirements for governance actors to exercise the identified competences, to make the framework operational and useful for practitioners, and to investigate the interdependencies between different competences of governance actors and the broader value chains, infrastructure and multi-level governance systems.

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