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The Interplay of Urban Energy Policy and Socio-technical Transitions: The Eco-cities of Graz and Freiburg in Retrospect

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Abstract

The cities of Graz in Austria and Freiburg in Germany have been perceived as ecological model cities since the late 1980s.This is shown by various international awards, press coverage and many visitors from other municipal administrations. Both cities have been well known for their attempts to bring about transitions towards more sustainable and low-carbon energy systems. The comparison of Graz and Freiburg over a period of two decades enables us to study how differing contexts, actor constellations and historic developments shape the transformation of energy systems towards greater sustainability. It is argued that understanding the role of cities for energy transitions requires a detailed examination of the coupled dynamics of socio-technical interactions across the levels of niches, regimes and landscapes on the one hand, and multilevel systems of governance on the other. At these intersections new, although spatially confined, socio-technical constellations of sustainable energy provision may emerge and be stabilised. Nevertheless, empirical evidence shows that it is misleading to conclude that true socio-technical transitions are taking place in these cities, even though a number of foundations for long-term change processes have been laid.

Keywords: eco-cities, energy transitions, multilevel governance, socio-technical systems

1. Introduction

The production, distribution and consumption of energy and emission of greenhouse gases are entrenched in and conditioned by large infrastructure systems—of energy, of

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transport or of our built environment. They are a constitutive part of our societies' metabolism with nature—the flow and exchange of resources—and are tightly interlinked with the social organisation of production and consumption in a growth-oriented economy. A substantial reduction of carbon emissions as urgently demanded in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) inevitably requires the radical restructuration of these socio-technical systems of energy, transport and the built environment. Increasingly, cities are being recognised as important arenas for innovative policies and action to reduce greenhouse gases and energy consumption (see for example, Betsill and Bulkeley, 2004; Brand, 2005; Bulkeley, 2006; Coenen and Truffer, 2012; Corburn, 2009; Coutard and Rutherford, 2010; Gustavsson *et al*., 2009; Keirstead and Schulz, 2010; Lindseth, 2004; Rutland and Aylett, 2008; Truffer and Coenen, 2012). Many initiatives and programmes for sustainable transport, sustainable buildings, energy efficiency or the use of renewable energies are crafted and implemented at the urban level of cities. However, what ambitious greenhouse reduction targets and related infrastructure policies require is nothing less than an 'energy transition'—i.e. a radical reconfiguration of the way we generate and use energy in cities and beyond. Given the global reach and interdependency of infrastructure systems—technologically, politically and economically—the capacity to achieve energy transitions primarily at an urban level may seem questionable. However, as we will argue in this paper, the distributed nature and specific socio-technical dynamics of such processes nevertheless makes cities an important arena of infrastructure transformation and a crucial nexus between different levels of governance and strands of socio-political discourse.

A growing body of research has been dealing with transitions of unsustainable current configurations of systems of energy, mobility or agriculture. As researchers of urban change have noted, dimensions of space and scale have so far been insufficiently integrated in these concepts (Bulkeley *et al*., 2011; Hodson and Marvin, 2009, 2011) and consequently underestimate the role of cities as crucial loci of change within broader transitions towards a less carbon-intensive world. This is where our research on eco-cities comes in. We are interested in reconciling and integrating the highly productive multilevel framework of transitions (as will be pointed out later) with an urban perspective with its particular logics of action. There are still a number of questions which need to be addressed in such an endeavour. To what extent can local infrastructures and socio-technical constellations be shaped independently from general patterns of provision and consumption, global or national market dynamics and higher-level policies (room for manoeuvring)? Can such deviations even influence the transformation of dominant, large, highly integrated infrastructures which (materially and institutionally) reach far beyond city boundaries (impact on the broader regime)? In other words, to what extent can alternative urban energy visions be implemented and stabilised at a local level and how is this process shaped by (and is shaping) socio-political and socio-technical contexts at different spatial scales? Our paper addresses these questions at an empirical and a conceptual level.

We will build our argument on the study of two cases of so-called eco-cities—the Austrian city of Graz and the German city of Freiburg—which both have been regarded as frontrunners of urban energy transitions. There are several reasons for choosing these cases. First, Graz and Freiburg are so-called second cities, meaning that they are not

world cities like London, Paris or New York with their often privileged position within national governance structures. Such smaller cities stand for an equally important and broad segment of cities which due to their limited size might have some advantages in implementing more fundamental policy changes. At the same time, 'second cities' can be strongly integrated in multilevel governance arrangements. Choosing 'eco-cities' as cases further gives us the opportunity to study processes of ambitious, goal-oriented infrastructural change. As we are particularly interested in the room for manoeuvring local actors have in transforming 'their' energy system, such frontrunner cities also give us an indication of the boundaries of purposive infrastructure change for cities of lower environmental profile.

In the following section, we first set out our conceptual framework for understanding goal-oriented, long-term changes of socio-technical systems such as energy infrastructures. We then comparatively investigate the energy transition efforts in the two cities of Graz and Freiburg. Finally, we discuss the potentials and limitations of such efforts and the implications our findings may have for our understanding of infrastructure transition dynamics.

2. Cities in a Socio-technical Transition Perspective

Science and technology studies (STS) have already gained a sophisticated understanding of the interdependent processes of social and technical change. Energy systems are socio-technical configurations where technologies, institutional arrangements (for example, regulation, norms), social practices and actor constellations (such as user–producer relations and interactions, intermediary organisations, public authorities, etc.) mutually depend on and co-evolve with each other. Innovation processes are becoming increasingly distributed and complex and are an outcome of the interaction between a multitude of actors, related to many different institutions and locations.

Many of these approaches analyse the interrelation of stability and dynamics of socio-technical change and refer to the multilevel perspective of technological change (MLP) (see for example, Rip and Kemp, 1998; Geels, 2004). This perspective distinguishes three levels of structuration: a level of confined technological niches as a source of variety, as a testbed for new technologies and as an 'engine for change'; a level of socio-technical regimes (for example, the energy system) providing stable structures and a selection environment for innovations and, thirdly, a broader context of the socio-technical landscape, which encompasses cultural norms, values or only slowly changing broader social structures.

The central element in this concept is the mesolevel of the socio-technical regime at which socio-technical configurations are temporarily stabilised and supported by a rule set that structures the socio-technical co-evolution process. The regime level incorporates the mutually reinforcing technological and institutional structures of specific domains such as the energy system and is characterised by a resistance to change (which, for example, may cause promising new technologies to fail). Nevertheless, under specific circumstances regimes may undergo fundamental transformations, especially if radical innovations (technological and/or institutional) coincide with strong outside pressures on the regime (Geels and Schot, 2007). The creation of novel technologies and radical change thus is brought about by the interactions of multiple levels: niche innovations creating novelty and building up momentum, destabilised regimes creating windows of opportunity for transformative change

and changes at the macro level of socio-technical landscapes creating pressures on the regime. This underscores the multidimensionality of processes of socio-technical change, the multiplicity of actors involved in the process and the embeddedness of local practices and niches in various social contexts with their own specific history and dynamics (Rip, 2012).

Socio-technical niches often play a key role for the emergence of radical innovations as they provide 'incubation rooms for radical novelties' and locations for the formation of social networks, the shaping of expectations and learning processes, for example, about technical specifications, user preferences, public policies or symbolic meanings (Raven, 2007; Schot and Geels, 2008; Verbong *et al.*, 2010). Different patterns of how niches may impact on regimes, such as niche accumulation or the hybridisation of niches with established technologies have been identified (Geels, 2002; Raven, 2007), although these linking mechanisms between niches and regime still lack analytical depth (Smith, 2007a). Further work has focused on niche-internal processes such as the formation of social networks, the shaping of expectations and learning processes (Schot and Geels, 2008; Verbong *et al.*, 2010), or on the growth and aggregation of niches as an interaction between local projects and increasingly global niches with an emerging community sharing cognitive, formal and normative rules (Raven and Geels, 2010). A core question with respect to sustainability policies centres on potentials and instruments to strategically manage the growth of such niches (Schot and Geels, 2008; Smith and Raven, 2012).

With the primary focus being on the transition of national infrastructure systems, cities and regions have rarely played a particular role in transition studies so far—and if so, then mostly as a context for niche experiments (see for example, Coenen *et al.*, 2010; Raven *et al.*, 2008). As Hodson and Marvin demonstrate, the role of place and differential capacities of city and regional-level actions to shape and manage technological transitions has largely been neglected (Hodson and Marvin, 2009, p. 532). World cities such as London have the potential to significantly influence and shape sustainability transitions at a wider scale and may play a powerful role as sites of mediation activities to co-ordinate systemic change processes (Hodson and Marvin, 2012). Only very recently, attention has also been drawn more generally to the importance of spatial dimensions for understanding transitions, such as place-specific impacts, territorial institutional embeddedness and in general a multiscalar conception of transitions which avoids simple spatial hierarchies and recognises the interrelatedness of different scalar levels (Coenen *et al.*, 2012; Truffer and Coenen, 2012; Raven *et al.*, 2012). Still, so far only a few studies have dealt with the governance of energy infrastructure change from a socio-technical point of view in cities (Graham and Marvin, 2001; Hodson and Marvin, 2009; Coutard and Rutherford, 2010; Späth and Rohracher, 2011; Bulkeley *et al.*, 2011; Maassen, 2012) and in regions (Smith, 2007a; Späth and Rohracher, 2010, 2012).

In our analysis of the cities of Graz and Freiburg, we want to build on this strand of research which highlights the importance of spatial perspectives and the crucial role of cities and regions in transition processes. We will focus on the particular local dynamics of energy systems change: which instruments and strategies are used to make cities' or regions' energy production and use more sustainable? Which logics of action, which motivations, visions and actor coalitions shape these place-related strategies? How is local action and capacity to change interlinked with and dependent

on multiscalar relations, such as globalisation processes, and national frameworks? With this analysis, we seek to explore ways in which a recognition of the important role of cities and regions in energy transitions can be taken up in a multilevel perspective on socio-technical transitions: Are cities really just locales for niche experiments? Are local actions mediating between the niche and regime level and have they a particular function in facilitating and stabilising change processes? Or are they particularly important for embedding such transitions into broader socio-political dynamics beyond the energy system?

3. Dynamics of Change in the Eco-cities of Graz and Freiburg

Graz and Freiburg are both mid-sized cities of less than half a million inhabitants and administrative centres of their respective province or smaller region. In both cases environmental and energy initiatives became emblematic for city development. From the 1980s onwards the cities assumed a pioneering role in various fields of environmental, energy and climate policy and were increasingly perceived as environmental model cities, not only in their countries but also internationally.

The Austrian city of Graz is located at the southern slopes of the Alps. With around 255,000 inhabitants it is the second-largest city in Austria and the capital as well as administrative centre of the province (Bundesland) of Styria. Graz positioned itself as an eco-city and has been awarded various European and international prizes for its activities and achievements in this field, such as the Greenpeace Climate Protection Award in 1993 and the Sustainable Energy Europe Award in 2008. Graz was also the first European municipality to be awarded the International Sustainable City Award by the European Union in 1996.

The German city of Freiburg with some 220,000 inhabitants is located in the southwest corner of Germany. It is surrounded by the slopes of the Black Forest and opens to the plain of the Upper Rhine Valley. Since the early 1990s, Freiburg is well known not only for an outstanding living quality but also for a set of remarkable environmental policies. In 1992, Freiburg was chosen Germany's Environmental Capital for its pioneering environmental achievements. Many awards and titles followed, such as Federal Capital of Climate Protection (2010) and Most Sustainable Large City of Germany (2012).

The following two cases of local 'sustainability transition processes' build mainly on the analysis of regional and national media; various published and unpublished documents produced by the administration, environmental activists and researchers; personal experiences of the authors of this paper who both for many years accompanied the green city development in either Graz or Freiburg as advisors; and finally semi-structured interviews with five to seven core actors of the transition process in each city. In line with other studies of transitions or niche development, these data were used qualitatively to reconstruct the formation of actor networks, shifts in discourses about urban environmental policy as well as emergence and development of policy instruments.

3.1 Graz on the Way to an Eco-city

Formation of a policy network. Graz did not have a particularly strong environmental record until the end of the 1980s. On the contrary, the city was confronted with an increasing deterioration of its air quality which to some extent was due to residential

heating and traffic, but to an even larger extent a consequence of its geographical location in a basin. This culminated in the so-called smog winter of 1988/89 when public pressure mounted to do something about this abysmal environmental situation. Legislative pressure was also exerted at provincial level, requiring municipalities located in 'air sanitation areas' (which mainly applied to Graz and a few other places in Styria) to draw up environmental plans for improving the situation.

At the same time, a group of engaged citizens became active in the field of urban environmental and energy policy. Getting to know each other as a critical opposition group within the local social democrats, this network of actors and its affiliates became strategically positioned and distributed within city administration and politics, including the city councillor responsible for waste and energy (an architect and planner), a member of the town parliament and energy expert and other activists belonging to the energy group within the physics department of the Technical University. Two professors of this department—one a member of city parliament and the second one later director of the Austrian Energy Agency—had been very active in the late 1970s in fighting the commissioning of a nuclear reactor in Austria. Until then the environmental department was a minor technical department with almost no staff. This situation changed dramatically with the new department head, his collaborators and the network they could draw upon.

In retrospect, we see how external pressure on the city administration and politics created a window of opportunity for personal and institutional changes. Opportunities were seized by a small but well positioned and environmentally engaged group of actors who set up a crucial base for further environmental activities and established nodes of a network spanning across municipal policy, administration and groups outside the municipality (research, environmental groups).

Flourishing programmes and initiatives. The centre of environmental politics in Graz was seized by the new head of the environmental department who became an entrepreneur within the municipal administration. The major environmental initiatives and innovative programmes were set up in the first half of the 1990s: the programme 'Eco-city 2000' as the first Austrian 'Local Agenda 21' programme, the 'Municipal Energy and Climate Concept' and various other initiatives such as 'Eco-profit' or 'Eco-drive'. At that time, Graz also became the first Austrian member of the 'Climate Alliance of European Cities' (Klimabündnis) with a greenhouse gas emission reduction target of 50 per cent until the year 2010 (with 1987 as the baseline).

Both the environmental and the energy programmes had comprehensive and integrative perspectives, drawing on the input of research institutes, involving various departments of the city administration and addressing energy and environmental issues as cross-sectional policy issues. Moreover, the documents produced were not so much traditional policy documents with policy targets and measures for the city administration, but action plans relying on a broad range of actors and making detailed suggestions for the implementation of various activities. The municipal energy and climate concept was developed in a participative process involving seven thematic stakeholder fora with participants from NGOs, companies, research and municipal utilities.

Many of the initiatives were advanced in other aspects, too. Graz was one of the early movers to implement energy demand-side management programmes. It also adopted energy contracting models for the refurbishment of buildings and the switch to district

heating or renewable fuels, and launched a 'solar initiative' supporting the feeding-in of solar thermal energy into the district heating system in summer.

Doubtlessly an important element for the actor dynamics were the international environmental awards and the public attention they drew to Graz. Even though many of the prizes were based on the ambitious programmes more than on the much slower implementation process, they were success stories for politicians and set in motion a self-reinforcing process with the department head "getting anything he wanted", as one of the interviewees expressed it. The bases for such momentum building for sustainability transition were thus not so much changes in the physical infrastructures or environmental policy outcomes, but rather the discursive dynamics of innovative concepts, international recognition and awards, and public appreciation of the eco-city identity.

A crucial institutional change during this time was the establishment of an Energy Agency as an important intermediary and driver for further change processes. The Energy Agency acts as a knowledge broker between municipality, research, companies and civil society. It organises stakeholder participation processes and is highly functional for connecting Graz to various green energy networks and programmes at the European and international levels.

The eco-city in stagnation. Despite these long-term institutional changes and programmes which still contribute to energy system change in the eco-city, Graz seems to have lost much of its political and public dynamics since the turn of the century. Ironically, the main success factors of environmental change in Graz—namely the entrepreneurial spirit of a few key persons in the city administration and the self-reinforcing image creation of Graz as a model eco-city—turned out to be an 'Achilles heel' for further development. The entrepreneurs became embroiled in a finance scandal and left the administration, while the eco-city image was replaced by new brands and visions like 'cultural capital' and 'city of design'. Moreover, the effects of new regulations such as 'energy market liberalisation' at the national and EU levels led to the partial privatisation of the municipal utilities and inhibited the municipal capacity to directly influence the urban energy system. Nevertheless, significant infrastructural and institutional changes including the Energy Agency, a much more powerful department and various programmes remained in place, even when the momentum was partially gone. With the recent coalition of the green and the conservative parties in city government and energy and climate change high up on the public agenda again it remains to be seen whether a new phase of eco-city development in Graz is about to commence.

Graz: a sustainable energy transition? To what extent can the eco-city development in Graz qualify as a sustainability transition? Looking back on roughly two decades of development, a significant number of technical and organisational measures has been implemented—for example, a substantial extension of the district heating network, energy efficiency and pollution reduction in a large number of local companies, planning of new ecological city districts and a municipal bus fleet running on biodiesel from locally collected cooking oil residues.

From a technical perspective, most of these changes qualify as gradual improvements rather than disruptive transformation of the municipal energy infrastructure. At the same time, however, they constitute new socio-technical configurations with

potential for larger long-term impacts on the energy system in Graz. Two short examples shall stand for these new socio-technical relations at play. First, Eco-profit is a programme supporting the voluntary adoption of energy efficient production processes in companies through subsidised consultancy and publicly visible networks of green companies. As much as it is about eco-efficiency improvements in more than 100 companies in Graz currently, this programme is about system building—the creation of a nodal agency, the training of consultants, the creation of linkages between companies in the 'Eco-profit Club' with regular meetings and workshops, and the creation of publicity for companies through prices, labels, etc. Moreover, Graz has supported various other European cities in setting up similar schemes. Secondly, another socio-technical innovation is the increased use of 'energy contracting' where an intermediary energy service company recoups investments in energy efficiency through the reduction of energy costs. Contracting has become a model for various private and municipal projects—for example, on combined heat and power generation, solar thermal collector fields, refurbishment of buildings and recently for the exchange of all traffic lights in Graz with efficient LED lamps. Contracting changes the investment decisions and ownership relations in sustainable energy projects (for example, third-party ownership of solar collectors), but it also creates competence centres for the assessment and carrying out of ecological investments and it shifts the emphasis from energy technologies to energy services which the contractor guarantees for the client.

Although most of these socio-technical innovations had already been introduced during the heydays of the eco-city development in the 1990s, they have established development trajectories through in-built drivers and agencies which still keep up momentum even as political support has diminished. Some of these programmes and projects are typical socio-technical niches for nurturing and experimenting with emerging technologies—for example, the biodiesel bus fleet, advanced eco-buildings or a hydrogen refuelling station for cars—but most of the examples already mentioned are gradual socio-technical and institutional reconfigurations within the urban energy regime, embedded in broader energy system or administrative contexts, such as liberalised energy markets, privatisation pressures for municipal infrastructures, or changed regulation at regional or national levels. We will come back to these questions of regime change in our discussion section.

3.2 Freiburg: Former 'Environmental Capital of Germany' becomes 'Green City'

Although there are many parallels, Freiburg's story of environmental policy and change also differs in many respects from that of Graz (see also Späth and Rohracher, 2011). The beginnings of its dynamic development were not so much rooted in a situation of locally mounting environmental pressure and concerns, but much more driven by the ambitious vision to reduce the dependence on what were increasingly perceived to be dangerous energy sources: coal and nuclear energy. Plans to build a nuclear power plant nearby mobilised strong resistance in the mid 1970s and had to be finally dropped in the early 1980s. Since then, a broad range of environmentally engaged civil society initiatives have been able to build up and keep up momentum for a local energy transition.

As early as 1986, the city council of Freiburg decided unanimously on an 'energy supply concept', which included a priority for energy saving, the objective of increasing the share of renewable energy (solar, water,

landfill gas) and a commitment to reduce the share of nuclear energy to zero.

Since the city has grown by more than 10 per cent over the past two decades, a significant decrease in the absolute consumption of energy could not be achieved. However, the municipality and private actors mobilised strong efforts to increase the efficiency of energy transformation processes within the boundaries of the city. The combined and therefore efficient generation of heat and power (CHP) were strongly promoted for its savings in primary energy. Meanwhile, about 50 per cent of electricity is generated in highly efficient CHP plants (Lange *et al.*, 2010). Several connected district heating systems (with heat generated partly from landfill gas and wood chips) have been systematically expanded to newly developed districts and are now serving about 12 per cent of the city's population. This expansion has been continued right into the 21st century and synchronously with a particularly strong policy to reduce the energy consumption of newly built houses (Späth, 2005).

Freiburg's policy of imposing high standards of insulation is widely acclaimed to be 'best practice' for improving the energy efficiency of new buildings. For plots sold by the municipality, and for development sites covered by a municipal development scheme, the city ensured by contractual arrangements, that specific building standards are met—sometimes exceeding (national) legal requirements by up to 30 per cent. The so-called Freiburg low energy building standard, which the city council decided upon in 1992 and 2005, required obligatory investment costs in Freiburg to exceed national requirements by about 5–15 per cent in the beginning—but the national standards regularly caught up after 4–5 years. In 2008, the city council decided to tighten the standards again and now the 'passive house standard' (which means basically reducing heating demand to around 15 kWh per square metre per year) is required for all new buildings with a few exemptions. Due to a decision of the city council from 2007, it is required for all areas under development to commission a consultancy comparing the feasibility of ecological energy supply options with a baseline scenario (currently: gas-fired condensing boiler technology plus solar collectors). The most environmentally friendly energy supply option has then to be implemented provided it can be realised with a cost increase of not more than 10 per cent compared with the standard option.

To achieve the second objective—increasing the share of renewable energy sources—is challenging too. By now six wind turbines with a capacity of 1.8 MW each have been installed within the city boundaries. The investments are largely based on the private equity of residents. The support of the city's administration was crucial for these projects, given a strong resistance from within provincial authorities. Some limited potential for hydropower generation within the area has been developed by means of privately owned, small turbines which have slowly increased in number over the 1990s and 2000s. In 2012, the capacity of photovoltaic generators installed within the municipal boundaries exceeded 25 MW_p, which is remarkably high in comparison with other German cities of this size.

One could argue that this building up of relevant generation capacity was strongly dependent on the feed-in tariff—i.e. national legislation. The early uptake in capacity for thermal use of solar energy (collectors for hot water) during the late 1990s, however, was largely achieved on the basis of investment subsidies paid out by the municipal utilities and funded by a specific (local) levy on electricity consumption.

Engaged experts and citizens for an energy transition. Freiburg is base to a wide range of research organisations, companies, lobby organisations and individuals which advocate renewable energies, mainly solar, and environmental technology and policies. Besides a Fraunhofer Institute on Solar Energy Systems (FHG-ISE) and the Institute for Applied Ecology, also the International Solar Energy Society (ISES) has located its world secretariat and the International Council on Local Environmental Initiatives (ICLEI) its European secretariat in Freiburg.

These research and lobbying organisations were to a large extent conceived and established in the context of a milieu of collective resistance and citizens' action against plans for a nuclear power plant near Freiburg. Later companies were also founded—for example, in 1993 a regional association for renewable energy, which together with partners in 1999 set up a regional energy agency. Although Freiburg is traditionally not a site of industrial production, PV modules and also more recently, concentrated PV power plants have been not only developed but also produced in Freiburg. Some of these organisations are a constant source for highly informed 'activists' developing ideas for opposing the cities' environmental, energy and climate policies. These individuals are not formally organised, but are usually informed on each other's activities, and informally meet on various occasions. Their vision of an alternative energy system and their position on energy-related matters is shared by many citizens who are not professionally involved in energy issues, but who are nevertheless well informed, as waves of 'letters to the editor' in the regional newspaper or the success of some *ad hoc* signature lists and petitions prove. For example, when experts voiced concern about the 'green' electricity product of the regional energy provider 'Badenova', more than 4000 customers of the company changed to a more ambitious and trustworthy provider with no relation to nuclear energy and an image of being an 'electricity rebel' (Energiewerke Schönau). This movement, which was absolutely unco-ordinated—as all usual suspects assure—put enough pressure on Badenova to make it completely overhaul its green electricity product and to switch to a more ambitious strategy of electricity procurement.

A sustainable energy transition in Freiburg? To what extent did these developments result in durable socio-technical reconfigurations? This can be answered by looking at two characteristic examples. First, to prescribe particularly demanding standards of insulation for new constructions wherever possible most likely did not only affect the quality of the buildings to which these prescriptions directly applied. The executing companies and planners adapted their own standard procedures and now tend to offer low energy solutions to any customer. Besides, we described how the 'Freiburg low energy standard' repeatedly proved the feasibility of tighter regulations of buildings, which were also later adopted at the national level. A municipally owned housing company, a research institute and other actors are currently shifting standards again by refurbishing some of Freiburg's high-rise buildings from the 1970s to near passive house standard.

Secondly, the role of the local utilities (gas, electricity, water), which merged with other municipally owned utilities of the region to create Badenova in 2001, illustrates another important characteristic contrasting with the case of Graz. Although nearly half of the shares of Badenova once had been sold to Thyga, a Bavaria-based subsidiary of the private energy company

'e.on', the operations of the regional utility continuously helped to implement the energy political objectives of the city council, administration and citizens. With parts of the money gained by the privatisation, an Innovation Fund for Water and Climate Protection has been set up, which is now endowed with 1.84 million EUR/year. Many local energy experts at the time warned that this fund could have little effect but distract from the fact that the company's policy would be dominated by shareholder value orientation instead of climate protection. But it turned out that the managers and board of Badenova (headed by the mayor of Freiburg) appreciated the importance of fulfilling the regional customers' expectations of a green and innovative energy supplier. Consequently, Badenova continued to develop renewable energy end efficiency projects. Meanwhile, the shares once sold to Thyga have been bought back by a consortium of municipalities and the company again is completely in public hands.

4. Discussion

Our case studies of Graz and Freiburg demonstrate that quite far-reaching changes can be achieved in energy infrastructures and socio-technical constellations at the city level. Although not a fundamental system transformation, we see 'regime variations' emerge at a local level which on various counts are significantly more sustainable than the nationally and internationally dominant energy regime and which also facilitate changes beyond the city (advanced standards, model for other cities, etc.).

These deviations are doubtlessly constrained (and need support) by institutions, policies, interests and actor constellations at regional, national and EU levels. The cases of Graz and Freiburg also illustrate the variability of the dynamics of sustainability-related socio-technical change at city level across specific national and regional contexts and the influence of external pressures and circumstances (for example, air quality situation, Tchernobyl nuclear accident). They further reveal different ways to build up social momentum for change (e.g. the role of independent energy experts and environmental activists in Freiburg, a well-positioned actor network with energy change ambitions within the administration of Graz), the existence and use of windows of opportunity and the creation of self-reinforcing dynamics (for example, building up an eco-city image which implies continued action).

Municipal policy in combination with support and pressure from civil society contributed to the transformation of crucial urban infrastructures. This includes the use of renewable energy along with the extension of district heating networks and combined heat and power generation, efficiency improvements of the building stock and tighter standards for new buildings, development of ecological city districts and energy efficiency gains in industry. Both Graz and Freiburg were rewarded with national and international prizes and public visibility for these efforts to make their energy systems more sustainable.

However, coming back to our introductory questions, we have to ask: do these changes indicate that the regional or municipal level yields sufficient capacity to influence the transformation of dominant, large, highly integrated infrastructures (materially and institutionally)? Examining our empirical material, we cannot state that the energy systems have changed profoundly and have been decoupled from the broader socio-technical regime. For such a radical transformation, the influence that can be exerted at a local level (in mid-sized cities) is limited. However, dynamic interactions within and between cities have brought about new

socio-technical constellations which seemingly generate momentum for further change at the regime level. In particularly, the emergence and solidification of institutional and organisational innovations (for example, contracting, energy agencies, strong municipal energy departments and re-municipalisation of utilities) may result in sustained pressure on the broader regime.

Yet the changes and policies in Freiburg and Graz do not quite fit the niche-regime dichotomy of energy transitions we started out with. Both cities do not just foster technological niches (for example, via support schemes for solar water heating). They are more importantly arenas or socio-spatial structures which span across niches and regimes: deviations emerging locally strongly interact with the global energy regime (for example, in the form of utilities following alternative business strategies, distributed generation capacity, etc.). At the same time they are traded explicitly as local actions—for example, aiming to be copied in other cities. These new hybrid niche–regime configurations hence are mediated by a logic of urban action which differs from the logic of niche variation and selection by regime structures. Municipal activities also depend on the positioning within multilevel governance contexts (control over utilities, coalitions with other cities) and specific, often contingent actor constellations (such as the policy networks in Graz). At the same time, regimes appear to be more heterogeneous and malleable than the notion of a transition between two consolidated systems suggests (for example, from fossil-fuel based to a sustainable energy system). It is obviously possible to create and maintain particular urban energy system constellations, such as a CHP-based energy supply system in Freiburg, even within dominant regime patterns at national or global level.

While municipalities in our study did not have the financial resources and administrative power to substantially overhaul their energy infrastructure, they (together with other organisations and networks) commanded sufficient governance capacities (for example, funding resources, organisational support, alignment and co-ordination of actors) to change institutional structures, create new organisations and stabilise new pathways for change which in the longer term may also more fundamentally transform material infrastructures. Examples from our cases are the linking of subsidies for new buildings to renewable heat provision (as achieved in Graz in collaboration with the provincial government) and the enforcement of advanced standards for new buildings (as the 'Freiburg advanced low energy building standard')—institutional changes which create a new dynamic for renewable energy generation and efficient building construction.

The alignment of relevant actor groups with the aim of energy system change turned out to be one of the major drivers of change. While in Graz a small policy network across city departments influenced the process, civil society actors (for example, concerned electricity consumers, environmental NGOs) interacting with the city administration pushed for a larger systemic and durable change in Freiburg. Likewise, regional utilities played a role in the preservation of an established socio-technical regime (Graz) and in challenging it (Freiburg). Still, many regime structures are beyond the reach of local action and so are major legal and administrative instruments such as regulation or taxation. However, the entanglement in a multilevel governance system not only restricts the capacity of cities to achieve change at a more radical level, but also opens up additional opportunities to solicit and embed change processes at other scales. The examples of Graz and Freiburg illustrate how local actors can sometimes mobilise the support required for urban environmental activities at the regional or national level:

Graz and the Province of Styria by co-operatively implementing a subsidy scheme for renewable heating and Freiburg with the planning of wind turbines and integrating heat networks by provincial authorities. The eco-city activities of Graz and Freiburg also show how cities try to extend their reach by using softer forms of governance—for example, involving local stakeholders and creating commitment and incentives for companies (without having the competency to regulate them). Examples are the eco-profit programme of Graz or a current programme to facilitate the application of combined heat and power technology in Freiburg.

In terms of challenging entrenched regime structures, cities and regions can serve as compelling discursive references and sites of feasibility demonstrations (Späth and Rohracher 2010, 2011, 2012; Späth, 2012). The success of implementing systemic changes such as new forms of implementing advanced building standards in local administrative structures or instruments like contracting to remove institutional barriers for investments in higher building efficiency have been frequently used as exemplars and legitimisation devices at national level and have shaped national discourses about the feasibility of energy system change. Developing and consolidating visions of alternative system configurations and (locally) demonstrating their feasibility may be as decisive for changes in the broader energy regime as experimenting with and learning about new technologies. Local actors consequently focus their efforts on showcase activities, promotion of 'best practice' and joining forces in networks of engaged cities. The networking of urban energy initiatives at national and/or international level transcends established levels of governance and creates additional arenas to challenge the incumbent energy regime (see for example, Bulkeley and Betsill, 2005, on the climate alliance of European cities). Both Graz and Freiburg have been highly active within such networks and have drawn additional motivation and momentum from comparison with and the support of other eco-cities.

5. Conclusions and Research Outlook

We can conclude from our analysis that, despite various contingencies and restraints, cities can provide a specific and potentially powerful social context for the partial reconfiguration of dominant socio-technical regimes towards greater sustainability. Under specific circumstances—like the external pressure in Graz to improve air quality or the civil society initiatives in Freiburg—systems of provision in cities can deviate substantially from dominant regime characteristics—for example, in the share of renewables and efficient co-generation used or in the energy efficiency of building stocks along with the institutional provisions they are embedded in (incentive structures, specialised intermediaries, etc.). Not least due to the inconsistencies, frictions and malleability of existing regime structures, there is often significant room for manoeuvring to stabilise and embed such deviations by local action.

However, we did not find a purposefully managed and effectively co-ordinated energy system transformation in Graz or Freiburg. What did take place rather was the development of broad visions of a green city future (in a nutshell: less air pollution in Graz and less reliance on 'dirty' energy sources in Freiburg). These discourses legitimised respective activities by concerned actor coalitions or organisations. The actor groups of Graz and Freiburg also differed slightly in form and translated the visions into different forms of concrete changes

and practices. Indeed, activities of urban actor constituencies were often driven by other interests and dynamics than environmental change. The intersections of a specific logic of socio-technical transformation (emerging niches vs dominant structures of the energy system) with socio-political dynamics across regional, national and international levels (for example, cities positioning themselves in global economic competition, dealing with social problems or trying to attract a young and educated population) often resulted in new (and arguably more sustainable) socio-technical configurations such as the construction of ecological 'model districts' or cleaner heating infrastructures which represent systemic changes in the urban energy system and blur the lines between niche formation and regime change. However, dependence on other socio-political dynamics may also mean that only certain elements of a more sustainable energy regime are developed instead of an integrated concept (for example, short-term, end-of-pipe measures for cleaner air instead of new approaches to mobility), or that the transformation dynamics lose momentum when certain alignments fall apart (for example, repositioning Graz as city of culture and design).

In order to understand and assess the interplay of such factors that stabilise or destabilise a socio-technical regime at a given time, it is thus important to study the discursive dynamics and emergence of institutions and actor coalitions at different levels of spatial reach. We have only explored the first steps in reaching a better understanding of the ways in which socio-political processes at different levels of spatial reach (or at 'scaled' governance levels) can shape the building up of momentum for change between the three levels of socio-technical structuration: niche, regime and landscape (for the interplay of district-level activities with national and EU-level activities, see Späth and Rohracher, 2010, 2012). Yet we found ample evidence that cities and regions can be at the heart of these dynamics of socio-technical change towards sustainability. Relating the dynamics of urban politics in its multilevel governance context to the multilevel perspective of socio-technical transitions provides novel conceptual insights that we expect to strengthen transition studies and it opens routes for further research.

Cases like Graz and Freiburg show us how malleable and heterogeneous socio-technical regimes are. The extent to which regimes are modified in an urban context not only depends on socio-technical niche–regime interactions, but also on further social, economic and political dynamics external to the socio-technical regime—also and even particularly at a city level (see for example, the positioning of Graz as a city of culture and design and of Freiburg as a 'Green City'). Cities and regions can be a very important arena of struggles about how to develop socio-technical regimes. Spatial aspects are therefore very important, such as the interplay of discourses and institutions of different spatial reach and the 'scaling' of infrastructural decisions across urban, regional, national and transnational arenas of governance. An assessment of factors influencing the transformative pressure on regimes, as we have demonstrated, therefore needs to be of 'high resolution'—i.e. it needs to take into account the micro level of the very local struggles about socio-technical futures in interdependence with the socio-technical system at large.

As we have emphasised, processes of change in a particular regime are closely interwoven with controversies and developments in other sectors and social spheres, particularly at a local level. Factors such as the positioning of cities in global economic competition may be highly relevant to stabilise eco-city trajectories and related energy regime changes. A better understanding of

modes of linkage between niches and regime, which has been identified as a desideratum for transition theory (for example, Smith, 2007b, p. 431), could be a result of drawing more attention to urban socio-political contexts as mediating and (de)stabilising forces. Understanding how momentum for change is created and how new configurations are strengthened hence needs a better coupling of the analyses of transition dynamics with those of institutional contexts and actor constellations at, among others, the city level.

This also opens up opportunities for a broader conceptualisation of the politics of transitions, which often has been criticised as being too consensual and harmonistic (for example, Meadowcroft, 2009). Our cases vividly show how transition policies are part of everyday politics, controversies and group interests in cities (for example, labelling Freiburg as 'Green City' rather than 'Solar City' after a new mayor took over). More emphasis hence needs to be put on the struggle of discourse coalitions about hegemony which—via local economic strategies and policies—can challenge and modulate otherwise strongly entrenched socio-technical regimes (Späth, 2012). Besides analysing discursive shifts in various arenas, and strengthening a spatial analysis as outlined earlier, further research may also profit from conceptual and methodological inputs from social movement studies. Finally, how political cultures are framed—for example, in a more deliberative and civil-society-based way in Freiburg as compared with Graz—may have an important influence on the potential of local actors to exploit the existing room for manoeuvring towards more sustainable infrastructures and needs. Such more generic pre-conditions of policy-making and urban interactions need to become part of a better understanding of urban transition dynamics too.

Further and more extensive empirical studies of urban infrastructure transformations towards sustainability will not only help us to understand the pre-conditions and improve the repertoire of action to reach such goals, but also bear the potential for further deepening theoretical concepts of socio-technical change.

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