Urban Energy Landscapes and the Rise of Heat Networks in the United Kingdom

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**ABSTRACT**

In the past decade, district heat networks have emerged as a key strategy for the UK government to achieve its 2050 decarbonization targets. Reports and analyses have focused on the technical and economic challenges of introducing networked heat provision in a country where this is a relatively novel energy service. Meanwhile, there has been little emphasis on the spatial and physical aspects of heat provision and their influence on the spatial development of cities. In this paper, we contribute to current debates on urban energy transitions with insights on the implications of heat networks to cities including scale, density, mixed-use, and materiality. The study reveals the embeddedness of energy services and the emergence of new forms of local governance that combine spatial and energy planning to realize new urban energy landscapes.

**KEYWORDS**

Heat networks; energy transitions; materiality; urban form; urban energy landscapes

**Introduction**

Heat and hot water for buildings comprises 40 percent of the United Kingdom’s energy consumption and 20 percent of greenhouse gas emissions (Committee on Climate Change [CCC], 2016). In the last decade, there has been renewed interest in heat networks (district heating and combined heat & power) because of their potential to contribute to national decarbonization goals (Bolton and Foxon, 2013; 2015; Weber, 2014; Winskel, 2016). This is evident in multiple UK policy documents that address climate change, renewable energy, and related issues.\(^1\) In 2011, about 2 percent of heat demand in the United Kingdom was served by heat networks including around 2,000 networks serving 210,000 dwellings and 17,000 commercial and public buildings (DECC/DCLG, 2009; Euroheat & Power, 2011). The Department of Energy and Climate Change’s *The Carbon Plan: Delivering Our Low Carbon Future* (DECC, 2011: 33) states that “the 2020s will be a key transitional decade in delivering mainstream low carbon heat from heating networks and in buildings, and will see the expansion of low carbon heat at scale into residential areas.”

Heat networks are characterized as an energy service that can simultaneously reduce carbon emissions from the building sector, address rising fuel costs and conditions of...
fuel poverty, and realize diverse and secure energy systems (DECC/DCLG, 2009; Homes and Communities Agency [HCA], 2011; Weber, 2014). However, heat has unique properties that differentiate it from other decentralized energy strategies. Distributed heat requires new modes of fuel supply, network design and construction, and operations and management that involve markedly different configurations of the built environment. In many ways, heat serves as a prominent example of “how energy transitions are spatially-constituted” (Bridge et al., 2013: 339, emphasis in original).

In this article, we contribute to the recent scholarship on urban energy transitions by using the case of heat networks in the United Kingdom as an exemplar of the spatial and material aspects of energy services. We argue that the materiality of energy infrastructure is an important but underplayed aspect of low carbon policy discourse. The findings of the study are derived from 16 semi-structured interviews conducted between 2011 and 2015 with a range of UK actors involved in the development of new heat networks, including trade organizations, mechanical engineers, architects, housing developers, and builders, as well as attendance at workshops and presentations for policymakers and practitioners. We focus specifically on heat network projects with a significant domestic component but the findings are also relevant to industrial and municipal heat networks. It is important to note that the discourses on decarbonization and heat networks in the United Kingdom continue to evolve at a rapid pace. This article provides a snapshot of these discourses rather than a comprehensive, definitive history.

We begin with an overview of the urban energy transitions literature and then focus on the material and spatial aspects of energy services. Through our empirical findings, we summarize three attributes of heat networks—scale, density, and mixed use—that characterize this energy service as inherently place-based, embedded, and urban. The rise of heat networks thus calls for a convergence of energy planning and spatial planning. We conclude that the spatial and physical attributes of heat networks reveal a need to address sustainable, low-carbon transitions at the local level through new forms of context-based governance and planning.

**Urban Energy Transitions**

Significant changes to current energy systems are needed to reduce carbon emissions. Scholarship by European researchers on transitions management, strategic niche management, the multi-level perspective, and related approaches have contributed to understanding the socio-technical evolution of energy systems (e.g., Verbong and Geels, 2007; 2010; Verbong et al., 2008; Smith et al., 2010; Grin, 2012; Verbong and Loorbach, 2012). A parallel aim of this work is to understand the multiple dimensions of energy provision and the implications of decarbonization strategies. The sustainable transitions scholarship has been critiqued for its neglect of the role of place (and particularly cities) in socio-technical change (e.g., Eames et al., 2006; Hodson and Marvin, 2006; 2009; 2010; 2011; 2012; Coutard and Rutherford, 2010; 2011; Bridge et al., 2013; Rohracher and Späth, 2014). As Hodson and Marvin (2009: 516) note, “While transition approaches acknowledge the interplay and interpenetration of different landscape (macro), regime (meso), and niche (micro) levels they say little explicitly about the role of the city and regional scale in processes of transition.” This has been addressed to some extent in recent years by a “spatial turn” in sustainable transitions scholarship (see Coenen and Truffer, 2012;
Coenen et al., 2012a; 2012b; Raven et al., 2012; Truffer and Coenen, 2012; Hansen and Coenen, 2015; Sengers and Raven, 2015; Wolfram et al., 2016). However, there is a continued need for more detailed analysis of how cities contribute to sustainable transitions.

Urban energy transitions provide an opportunity to understand the role of cities in socio-technical change. “Cities, as entities within which an ever-larger share of energy is used, are seen as simultaneously constituting a key target of such an energy transition, as well as a key ‘instrument’ in delivering it” (Rutherford and Coutard, 2014: 1354). Rather than using space metaphorically through ideas of niches, regimes, and landscapes (Bridge et al., 2013), the notion of urban energy transitions draws on ideas from the transitions literature as well as large technical systems, urban environmental governance, urban political ecology, and related literatures to provide situated and contextual accounts of changes in energy generation, distribution, and use (While et al., 2010; Bulkeley et al., 2011; Hodson and Marvin, 2011; Bolton and Foxon, 2013; 2015; Bridge et al., 2013; Rydin et al., 2013; Monstadt and Wolff, 2015; Walker et al., 2015). In this literature, urban energy transitions are viewed as assemblages of socio-technical relations that includes a heterogeneous combination of local and extra-local stakeholders, infrastructure networks, policies and regulations, and so on (Rutherford and Coutard, 2014). Bolton and Foxon (2013: 2197) summarize this perspective by arguing that “viewing cities as dynamic sites of transition where new relationships between supply and demand are being forged could have profound implications for the way in which we conceptualize socio-technical transition processes and infrastructure governance.”

This article builds upon the urban energy transitions literature by focusing on the material and spatial aspects of energy networks. Owens (1990: 53) argues that “the system of energy supply, distribution and use is related in significant ways to the spatial organization of society” while Bridge and colleagues (2013: 333) note that “energy systems are constituted spatially: the components of the system are embedded in particular settings and the networked nature of the system itself produces geographies of connection, dependency, and control.” Patterns of urban development and building design are influenced by energy systems and thus, changes to energy provision unavoidably result in changes to the spatial organization of cities (Rutherford and Coutard, 2014).

In addition to spatial aspects, materiality is an important and frequently underemphasized characteristic of urban energy transitions (Rutherford and Coutard, 2014; Guy et al., 2016). The material aspects of infrastructure are often portrayed as an “apolitical context or backdrop” (Monstadt, 2009: 1930) but we argue that these networks comprise a “vital materiality” that includes human actors and their physical surroundings bound up in socio-technical assemblages (Bennett, 2005; Guy et al., 2016). Critically, a focus on materiality opens up energy networks to a more contextual and relational perspective that includes a range of actors, logics, and practices that in sum produce the built environment while linking local contexts with global drivers (Lovell, 2007; Rutherford and Coutard, 2014; Karvonen, 2018). Moreover, an emphasis on materiality moves analysis away from the largely symbolic representations of low carbon agendas to better understand how these agendas are situated and constituted in specific places (Hodson and Marvin, 2012; Rutherford, 2014; Rutherford and Coutard, 2014).

Taken together, we can think of the spatial and material aspects of energy services as constituting an *urban energy landscape*. The notion of landscape “draws attention to the interaction of natural, technical, and cultural phenomena in a geographical setting,
and how these particular assemblages vary over space and time” (Bridge et al., 2013: 336). The urban energy landscape acknowledges that energy service provision is not only influenced by policymaking, technical specifications, and economic considerations but also the real-world contexts in which they are embedded. When studying low-carbon transitions, the landscape perspective draws our gaze to the spatial form of cities, settlement densities, the design of buildings, the use of materials, and the lock-in of existing infrastructure networks (Lovell, 2007; Bulkeley et al., 2011; Hodson and Marvin, 2011; Bridge et al., 2013; Calvert, 2015; Guy et al., 2016; Castán Broto, 2017). This embedded and relational understanding of energy networks “opens up a range of novel and productive ways of thinking about how the urban comes to have the structure and consistency that it does” (Latham and McCormack, 2004: 709). Energy networks constitute cities and urban energy landscapes provide a conceptual lens to understand how energy provision and urban development co-evolve.

**Heat Networks and the Urban Energy Landscape**

The current drive to roll out heat networks in the United Kingdom is a vivid example of how urban energy landscapes are conceptualized, contested, negotiated, emplaced, and realized. The United Kingdom has a long history of heat network initiatives stretching back to the 1910s. Heat networks can be found in 1960s and 1970s tower blocks, on single-owner hospital and university campus estates, and in a handful of larger schemes with multiple property owners in cities such as Woking, Sheffield, Southampton, and Aberdeen. The minimal penetration of heat networks in the United Kingdom (when compared to Nordic and Eastern European countries) is the result of a history of policy decisions including the nationalization of energy supply networks in the 1940s, the subsequent liberalization of these networks in the 1980s, and the long-term strategy of developing domestic natural gas as a secure energy source. In combination, these factors have slowed the introduction of more efficient and low-carbon energy services (Wilson and Game, 2002; Winkel, 2002; Department for Business Enterprise & Regulatory Reform [BERR], 2008; Roberts, 2008).

Following the emergence of heat networks reveals a range of actors occupying a complex and contested urban energy landscape that is largely absent in policy analyses that focus narrowly on technological and economic issues. Instead, we argue this energy service has important spatial and physical characters that are closely aligned with urban development processes. In the following sections, we characterize three spatial and physical characteristics of heat, namely scale, density, and mixed use. Our research shows that these characteristics comprise an indelibly *urban* form of energy service that are closely aligned with spatial planning and have important implications for local governance.

**The Scale of Heat**

Heat has unique scalar implications; heat networks are often sized somewhere between individual buildings and the universal grid. The large investment for heat generation equipment and distribution systems tends to require a minimum scale of development (although there are instances of small systems that serve an individual building). Referred to as decentralized, distributed, dispersed, embedded, or micro-generation (Alanne and
heat networks are typically designed to serve a complex of buildings in a tightly defined block, neighborhood, or district while providing some 10 kWth to 50 MWth of energy services.

At their largest size, heat networks can span an entire city (e.g., Vienna) or form an integrated web of multiple interconnected networks (Copenhagen). But in many cases, heat provision introduces a meso scale of energy production and consumption (Walker and Cass, 2007; Foresight, 2008; Watson et al., 2010; Hawkey et al., 2013; Webb, 2015). The meso scale sits somewhere between the micro scale of the individual building and the macro scale of national and international energy networks (colloquially referred to as “the grid”). The meso scale comprises distinct technologies and institutional frameworks and as a result, is often overlooked in energy policy debates in the United Kingdom. As Watson and colleagues (2010: 8) conclude, “there is no established tradition in the United Kingdom of either energy technology deployment or energy system governance and regulation at meso (regional or local) scales.” Instead, individual buildings are targeted with feed-in tariff policies, demand-side efficiency measures, and micro-generation incentives while funding for large-scale utility investment and upgrades are made to the universal grid.

Financial and operational considerations are the most common justification for targeting the meso scale for heat networks. A technical consultant we interviewed noted that “in terms of load, the bigger the scheme the more efficient your CHP becomes, the larger CHP you can get the more efficient it generally is, the longer you can run it for.” And for smaller schemes, “CHP doesn’t become particularly viable from a financial point of view.” A homebuilder echoed these comments, stating, “Seemingly anything below about 350 dwellings, it just doesn’t generate the revenues that they need to justify an initial infrastructure outlay.” Thus, heat networks are closely tied to the size of the network and its ability to demonstrate economic viability.

With respect to urban energy transitions, the focus on the meso scale frames local authorities as key actors in initiating, planning, financing, owning, and operating heat networks (Grohnheit and Mortensen, 2003; Hawkey et al., 2013). While local authorities have served as influential actors of energy services in many European countries, this is a novel occurrence in the United Kingdom. Here, there is increasing recognition that local authorities embody “long-term commitment to place, legal powers and duties, and control over assets and resources” (Hawkey et al., 2013: 24). In addition, large property developers are increasingly driving heat network rollout as part of their low-carbon commitments (BRE, 2013; Guy and Karvonen, 2016). Thus, heat networks differ from many other energy services because of their indelibly local character.

Density and Heat Services

In addition to requiring a particular scale of development, the high capital costs of heat networks require energy services to be delivered in the tightest space possible to maximize the number of end users. Thus, dense urban developments are ideal for distributed heat provision. A local authority engineer confirms the importance of density stating, “the thing that does it for London is the densification […] there’s more people packed into a square meter, which is great because you only have to do a little investment to get a lot of people.” The close proximity of building occupants was the principal logic for targeting tower blocks in the 1960s and 1970s. The verticality of towers provided sufficient
density of end users to justify the costs of heat generation and distribution infrastructure. A low-carbon housing expert we interviewed, reflecting on low-density housing noted that it gets really expensive to start feeding from a central district heating center, and the pipework has to go down all these different roads and individual roads [...] if you’ve got a house down a cul-de-sac, little bit tucked away, you’re suddenly up to £5,000 or £10,000, just to get to that one particular plot that’s slightly offset.

This perspective reveals an emphasis on financial efficiency rather than energy efficiency and reflects the contemporary neoliberal political context of the United Kingdom.

However, while density is used to finance the high first costs, there is a need to strike a balance between techno-economic optimization and end-user preferences. This is particularly evident with housing where there are significant pressures to design developments that will attract individual investors. A housing developer stated:

We went out to market for a scheme of 450 homes, and it might have worked more easily at that density to get the energy thing sorted out. Clearly you’d be talking more flatted developments which is easier anyway for the district heating stuff. But that was 2006 and that was before the housing bubble went bang and you get to 2009 and it was more and more apparent that that kind of density of development would not be probably desirable and anyway wouldn’t be viable because it wouldn’t be financed and wouldn’t be sold even if it was financed.

This professional perception is echoed in a report by the Homes and Communities Agency (2011) that recognizes the concerns of homebuilders about the marketability of houses served by heat networks that require higher densities. Moreover, this points to homeowner perceptions about heat networks and concerns about long-term cost, management, control, and reliability (Zaunbrecher et al., 2016). There is a clear tension here between the spatial attributes of heat networks and the economic drivers of the property market.

Density is not only related to the spatial extent of the pipe network but also the form of houses. Detached houses have much lower heat-energy efficiency than apartments and high rises. As Owens (1990: 68) notes, “other things being equal, detached houses can require as much as three times the energy input of intermediate apartments” for space heating. And while density creates tradeoffs with other environmental design strategies including natural light, solar gain, and ventilation, there is a general consensus that “density equals efficiency” (Holden, 2004; Mindali, 2004; Rode et al., 2014). Table 1 illustrates the correlation between building density and heat network costs for a range of building types. In this example, the cost per dwelling increases by a factor of four as development density decreases from a high-rise apartment block to detached or semi-detached houses.

Table 1. Comparison of building type, density, pipe length, and cost for various heat network configurations Source: TCPA/CHPA 2008

| Building Type                        | Form                           | Housing density [dwellings per ha] | Pipe length per dwelling [m] | Cost per dwelling [£] |
|--------------------------------------|---------------------------------|-----------------------------------|-----------------------------|-----------------------|
| High-rise apartment block            | Corridor access, 10 to 15 stories | 240                               | 6.75                        | 2,500                 |
| Medium-rise apartment block          | Corridor access, 5 to 6 stories  | 120                               | 8.0                         | 2,800                 |
| Perimeter block of flats and townhouses | Stairwell or street-level access, 3 to 4 stories | 80                       | 11                          | 4,100                 |
| Terraced street of row houses        | Street-level access, 2 to 3 stories | 80                       | 13                          | 5,300                 |
| Detached/semi-detached houses        | Street level access, compact street layout | 40                       | 19 to 24                   | 7,700 to 9,550       |
Mixed-Use and Heat Demand

Density is not the only consideration when designing heat networks; these networks also require high and consistent heat demand. The Energy Saving Trust (EST) (2009) suggests that heat generation plants need to operate for a minimum of 4,000 to 5,000 hours per year (or the equivalent of 13 to 14 hours per day) to be economically viable. To achieve this high demand, it is desirable to have a range of end users that use the heat services at different times of the day and different days of the year. Mixed-use developments, with a variety of domestic, office, industrial, and other uses, smooth out the residential peaks of high morning and evening energy demands to create a consistent heat demand profile to optimize operational efficiency (TCPA/CHPA, 2008; EST, 2009). And this is further complicated by seasonal changes in the demand and generation of heat.

As Roberts (2008: 4566) notes:

the ideal scheme would link those adjacent buildings with differing patterns of heat demand, such as adjacent schools, hospitals, student accommodation, government or local authority buildings [...] the same energy center can serve flats predominantly in the morning and evening, but a school during the day.

A consulting engineer we interviewed reinforced this position, stating that “the more diversified users you can get on it, the better really. Baseload then just rockets.” And a designer added that “unless you’ve got a significant heat load that is provided by a swimming pool, public sector building, [or] large office block, district heating schemes for residential uses alone are really just not economically viable.” Thus, diverse patterns of use concentrated in a limited area are required to make heat networks viable (Webb, 2015).

Owens (1986) estimates that by optimizing density and mixed use development, heat networks can improve the efficiency of primary energy end use by up to 100 percent. However, this requires careful planning to create an integrated development with the proper mix of buildings. This is illustrated in a mixed-use development where the loss of the heat network resulted in the loss of other amenities. A design team member reflected on the careful integration of various features to optimize the energy strategy for a proposed mixed-use development and how this collapsed during the 2008 economic downturn:

We originally had a small shop, a cafe, this community hall and this sort of spa, because the energy side was going to produce so much waste heat and so we were going to use it to power the hot tub arrangement. But district heating’s gone, the spa’s gone, the only thing we’re actually left with is a shop on the corner.

The density and mixed-use of heat provision points to a close coupling of the energy strategy with the physical layout and features of new projects. The requirements for density and mixed-use often involve fragile development arrangements that integrate energy services with the built environment.

The Urban Character of Heat Provision

The combination of scale, density, and mixed-use suggests heat networks as most appropriate for urban applications and a convergence of the choice of energy service with the physical design of the development.
Heat networks are more likely to be cost-effective in urban settings, where there are many buildings like blocks of flats where individual gas boilers may not be an option, and also commercial buildings such as hospitals and leisure centers that provide high and predictable heat demand. (DECC, 2013: 37)

This mirrors the sustainable urban design debates of the 1990s and 2000s about the Compact City and New Urbanism that highlighted connections between urban form, quality of life, and reduced resource consumption (e.g., Williams et al., 2000; Burton et al., 2003; Neuman, 2005; Jabareen, 2006; Farr, 2011). And today, there is “a strong congruence between action for urban sustainability and a desire to change the energy system” (Rydin et al., 2013: 634–635). Developments that are dense and mixed-use are understood to be more resource efficient and socially cohesive than sprawling suburban, car-centric developments. Conversely, this suggests that distributed heat provision is less appropriate for suburban and rural locations. There are strong correlations to networked infrastructure systems with high capital costs such as public transit (Owens, 1990) as opposed to other forms of energy services (including electricity and gas as well as renewables) that are much cheaper to build and modify over time.

This promotion of heat networks also has implications for low-carbon energy strategies. Renewable energy technologies such as photovoltaics and wind turbines are less effective in dense and mixed-use areas due to a lack of space and the presence of obstructions. A local authority engineer states:

From a point of view of renewables, a dense urban landscape’s no good for PVs, there’s not enough area, you get shading. It’s useless for micro wind, you just don’t get the airflows sort of around buildings.

This perspective is echoed by a trade group representative who states that

micro-generation gets more and more problematic the denser the size. There aren’t big enough roof spaces for PV [ … ] It makes more and more sense to have a communal solution of some kind, so district heating is that.

This indicates that the density required for distributed heat provision could make it more suitable in urban environments than other types of low-carbon energy. However, it is likely that future urban energy landscapes will not rely on a single “winning” technology, but will rather comprise a landscape of co-existing (and sometimes competing) alternatives.

These three characteristics of heat networks—scale, density, and mixed-use—emphasize how the UK government’s low-carbon heat network agenda can also be interpreted as an urbanization strategy that mirrors an energy strategy. A trade organization representative we interviewed stated, “Energy does shape where things are. It’s actually energy distribution networks which have a big influence on where employment is and commercial interests are and where people live.” The confluence of energy infrastructure and urban planning harkens back to scholarship from the late 1970s to the 1990s that considered the relationship between urban form and energy efficiency (see also Lovins, 1977; Romanos, 1978; Van Til, 1979; Owens, 1986; 1990; Summerton, 1992; Anderson et al., 1996; Nye, 1999). Owens (1990: 55) notes that “the energy crises of the 1970s stimulated considerable interest in the energy/spatial structure relationship and in the potential contribution of land use planning to energy conservation,” and we argue that a similar trend is now occurring with twenty-first-century low-carbon governance. Combined energy and spatial planning has
been commonplace since the 1970s in Scandinavian countries and in US cities such as Davis California and Portland, Oregon, but is only slowly emerging in the United Kingdom in conjunction with national carbon reduction goals. The pursuit of decarbonization and energy security in the United Kingdom will result in energy as a significant driver for land use changes in the future (Howard et al., 2009; Bridge et al., 2013).

Physical and Material Attributes of Heat Networks

Beyond their spatial attributes, heat networks also have physical and material characteristics that influence urban form. To avoid heat losses, distribution pipes are designed as linear networks to realize the shortest distance between generation and use. A local authority engineer noted:

I think part of that masterplanning process you would also consider the heat network, how it runs, because it does take up rather a lot of space. You have things like obstructions, bridge crossings, rail crossings, at least provision is allowed and made so you can bring the pipes in later, because putting them in later across major junctions and things like that is a pain in the arse [ … ] Pipework is a linear development, roads and rail systems are linear developments.

This linear configuration of heat networks reinforces the imperative for dense urban settlements, but also ones that can be designed with the shortest pipe runs to maximize economic efficiency. Again, this shows how heat provision mirrors transport infrastructure, where the length of the network and turns and bends result in higher costs and suboptimal performance. Beyond the distribution network configuration, the energy centers where the heat is generated require space and have a physical presence in neighborhoods (See Figure 1). A consulting engineer we interviewed noted that, “[Energy centers are] not small buildings. We need to find space for them at the planning stage.” Unlike electricity and gas networks, heat networks have a prominent local footprint because generation is located in close proximity to consumption, creating another spatial planning consideration for design teams to address.

Figure 1. The energy center at Graylingwell Park in Chichester is located in a historic water tower structure (left) while the energy center at the Park Dale zero-carbon housing development near Castleford is intended to blend in with the surrounding housing stock (note the chimneys) Source: authors
Thermodynamics also underpins the unique spatiality of heat networks. Similar to gas and water services, heat can be stored for use at a later date. This provides a distinct advantage over renewable electricity strategies such as photovoltaics and wind by decoupling energy supply and demand. However, the capability for storage requires space to accommodate storage tanks (See Figure 2). A mechanical engineer provides a succinct perspective on the issue of heat storage:

People just don’t understand [heat storage], they don’t want to put it in. It’s a pain. The first thing the clients say is, “Where am I going to put that?” And a lot of consultants will just say, “Well, chop that one in half and we’ll put in three of a smaller size.” But thermal stores should be tall and skinny; the taller and skinnier, the better for stratification.

The proliferation of heat storage in UK cities could provide an alternative to the massive gas storage tank structures that characterized British cities of the Twentieth Century. While heat stores and energy centers are much smaller in size than gas storage tanks, they have the potential to be a tangible and visible element of urban energy landscapes in the future. Such a heightened visibility of energy could be perceived as an aesthetic burden for urban residents, analogous to the NIMBY debates about wind turbines in rural areas. Conversely, it could be seen positively as a visual symbol of a city’s commitment to low-carbon energy alongside photovoltaics and green infrastructure.

Heat storage issues are perhaps less of an issue than the need for low-carbon fuel sources to produce heat. Heat generation facilities can be designed to use oil, diesel, or natural gas as a fuel source. However, a significant argument for introducing heat networks is that they provide the potential for transitioning to low-carbon fuel sources such as biomass (EST, 2009; Sustainable Development Commission, 2009; HCA, 2011; Hawkey, 2012). The introduction of biomass introduces new issues of space related to transportation and storage. Unlike oil and gas, wood chips and pellets cannot be pumped to the point of heat generation and thus, there is a need...
for frequent truck deliveries that create issues of local traffic congestion, noise, and safety. Furthermore, bulky cellulose fuel supplies require space for storage that can be significant and also introduce risks of fire and explosion if not managed properly. A design team member for a large housing development summarizes the biomass supply challenges, stating:

We’re looking at a district heating system, so you’ll need fuel pellets in an energy center, in a boiler house, which will impact upon deliveries. We have to consider the physical aspect of it all; they’re delivering every two weeks or four weeks.

Finally, biomass requirements will create new interdependencies with non-urban areas where the material can be produced in large volumes.

In combination, the physical and material properties of heat services create novel challenges (see Pierce and Paulos, 2010). Linear distribution networks, storage tanks, energy centers, and biomass storage units comprise a new urban energy landscape that requires integration with other infrastructure networks and the built environment. It is not simply a matter of “dropping in” a new energy infrastructure system but of negotiating the multiple factors that comprise the built environment and its relationship to energy services. Thus, the rise of efficient, low-carbon heat provision requires new forms of local governance that consider energy and spatial planning simultaneously.

**Governing Urban Energy Landscapes**

The urban energy landscape produced by heat services creates a strategic opportunity for local and regional authorities to be key actors in energy transitions. It demonstrates a compelling convergence of energy planning and spatial planning at the local and regional level. Seen this way, local authorities are understood “to have a critically important role in setting the strategic context for, and initiating the development of, district heating networks within the UK’s towns and cities” (BRE, 2013: 8). Local stakeholders see in heat networks opportunities to fulfil their sustainability and climate change agendas, attract new economic development, address fuel poverty, develop autonomy from national energy networks and ensure security of supply (Bolton and Foxon, 2013; 2015; Platt et al., 2014). Because of the inherently local character of heat networks, there is a need for expertise in local conditions and dynamics that also connect up to regional, national, and international scales (Roberts, 2008; Hawkey, 2012; Hawkey et al., 2013; Weber, 2014).

In the United Kingdom, local authorities have not been involved in energy provision since the 1940s, and they continue to have limited abilities to govern energy infrastructures due to a deficit of technical, legal, and commercial expertise (Hawkey, 2012, 2014; Hawkey et al., 2013; Weber, 2014; Bolton and Foxon, 2015; Webb, 2015). Meanwhile, energy policymaking and regulations occur at the national level with little opportunity for local authorities to shape these debates. Unlike other countries such as Denmark and the Netherlands, Weber (2014) notes that the UK government has not provided an enabling mechanism to develop heat networks. Hawkey and colleagues (2013: 29) conclude that heat networks are “caught in the squeezed middle ground between greater efforts at large-scale national infrastructure investment on the supply side, and individual household incentives on the demand side.”
To respond to the rather weak role of local authorities in heat networks, several initiatives have emerged that comprise a “softer” form of energy governance (Rohracher and Späth, 2014). This involves coalitions of stakeholders that work in particular localities. Longstanding advocates of heat networks such as the Association for Decentralized Energy and the UK District Energy Association have been joined by Government agencies including the Department of Energy and Climate Change (DECC), the Department for Communities and Local Government (DCLG), and the Homes and Communities Agency (HCA), as well as advocacy organizations such as the Carbon Trust and the Energy Saving Trust. There is an understanding that coalitions of local actors are needed to create the conditions and to institute actions for low-carbon transitions while recognizing and accommodating broader national and international influence and pressures (Hodson and Marvin, 2009). These activities recognize heat networks as a context-specific energy service with the need for targeted support at the local level (Bolton and Foxon, 2013).

The emergence of heat mapping activities across the United Kingdom also demonstrates the local focus of the heat agenda (Hawkey, 2012; DECC, 2016). Heat mapping involves the identification of “hot spots” where heat demand is highest and where heat networks will have the greatest economic viability. This points to the “circumstance-specific nature of heat demand” (DECC, 2013: 6) and the range of contextual factors that need to be considered when making strategic and informed decisions about where to design, build, and operate heat networks. This is analogous to transit-oriented development strategies where clusters of buildings are planned near mass transit stops to maximize infrastructure investments.

The UK government has made a significant push to accelerate the local development of heat networks, not only in its policy documents on low carbon and energy strategy but also in its technical and economic support. This is exemplified by the Department of Energy and Climate Change’s Heat Networks Delivery Unit (HNDU), a support department founded in 2013 to enhance the capacities of local authorities to plan and implement heat networks (Whitehead, 2014; DECC, 2015). Support includes guidance and technical and economic expertise as well as grant funding. Since 2014, HNDU has completed six rounds of funding and awarded £14 m of funding to 139 local authorities in over 200 projects. Local authorities are required to provide 33 percent match funding for projects related to heat mapping, energy master planning, feasibility studies, detailed project development, and commercialization. HNDU is driven by a strong focus on the investment opportunity of heat networks, mirroring the UK government’s investment of £300 m from 2016 to 2020 to leverage up to £2b in private capital investment (HM Treasury, 2015).

Meanwhile, there is a significant amount of activity to build capacity of local authorities in energy masterplanning. An example of this is the three-year Spatial Planning and Energy for Communities in All Landscapes (SPECIAL) project to support the activities of local authorities in the planning and implementation of local energy efficiency and renewable energy strategies (SPECIAL, 2016a). The project, funded by the Intelligent Energy Europe Program of the European Union, ran from 2013 to 2016 and was underpinned by the acknowledgement that “planning has a fundamental role to play in creating and supporting spatially appropriate energy solutions based on an understanding of settlement areas, land uses, and the built environment”
Led by the Town and Country Planning Association (TCPA) in the UK and including planning organizations in the UK, Germany, Hungary, Ireland, Italy, Greece, Austria, and Sweden, the project targeted heat networks and other local energy strategies by bridging energy planning, spatial planning, and master planning. The project provided training and capacity building; knowledge exchange; pilot projects; and the development of policy statements to train planners about the technical and policy aspects of energy infrastructure and to position them as facilitators of low-carbon energy transitions.

Beyond the UK government’s support for local authorities and European planning organizations’ work at capacity building and integration of spatial and energy planning activities at the local level, there is a significant amount of work happening on the ground. The Greater London Authority (GLA) exemplifies these actions through its heat network activities in multiple boroughs across London as part of the region’s ambitions to cut carbon emissions by 60 percent by 2025 (GLA, 2011). The 2011 London Plan requires all boroughs “to embed policies and proposals within their Local Plans in support of establishing decentralized energy network opportunities, with particular focus on heat networks” (GLA, 2014: 7). The work is underpinned by the London Heat Map, first introduced in 2009, that identifies locations for further study (GLA, 2016). They have also developed guidance documents that include specific information on technical design and standards, finance and economics, construction management, contractual issues, and revenue management (GLA, 2013, 2014). Moreover, the GLA has worked in conjunction with private consultants to produce 13 energy masterplans between 2012 and 2016 with a central emphasis on heat provision (GLA, 2016). A local authority engineer we interviewed reports that:

Now we’re going into those heat dense areas and coming out with energy masterplanning, which is really establishing where the network is, how far the network could realistically run and be economic or market competitive, given where the demand is and given what’s available as sources of heat.

The above three examples demonstrate very different motivations for promoting and supporting heat networks. The UK government is interested in investment while the SPECIAL project focuses on the integration of spatial and energy planning and the GLA is working to get these projects up and running. Heat networks point towards the re-emergence of local authorities as energy service providers. This requires situated and context-specific expertise that leads to tangible design and construction activities. The local governance of heat networks points to a reallocation of decision making, expertise, ownership, and responsibility for energy services (Alanne and Saari, 2006). Here, socio-technical transition is less about a clear, linear mode of innovation and more about orchestrating and aligning existing dynamics in a particular place (Weber, 2014). This suggests that transitions of urban energy landscapes are not simply dictated by the UK government and implemented at the local and regional level but rather involve an interactive and relational mode of steering socio-technical change (Hawkey, 2012).

**Conclusions**

Heat networks raise issues that are typical of all infrastructure networks, including financial and technical challenges, policy and planning considerations, and long-term
operations and maintenance obligations. However, these networks also have spatial and material properties that are frequently overlooked by policymakers in the pursuit of low-carbon transition pathways. The emphasis on heat networks as a decarbonization strategy by the UK government provides a vivid example of how energy services are spatially constituted. The material aspects of heat provision create an urban energy landscape that requires the convergence of spatial planning and energy planning to situate energy service provision within particular contexts. There is an increasing recognition that energy systems and urban systems co-evolve; in essence, “the energy question is inherently an urban question” (Rutherford and Coutard, 2014: 1371).

The convergence of urban development and energy planning complicates sustainability transitions by introducing a whole host of issues that go beyond techno-economic considerations of energy supply and demand to include urban planning and development issues. We argue that energy planning needs to be considered alongside other spatial planning issues such as transportation and housing rather than as part of national policy strategy or as individual building interventions. Meanwhile, it is important to recognize that the existing urban networks and configurations have path dependencies that make changes to energy provision more challenging. As Naess and Vogel (2012: 48) note, “The inertia of the existing built environment makes radical changes in the environmental performance of urban land use and infrastructure a long-term affair.” Thus, while introducing new infrastructure services clearly requires stakeholders to address economic and technical challenges, our analysis suggests the need to engage in processes of spatial planning to integrate these services in their local contexts and over long time scales.

The convergence of energy planning and spatial planning places local authorities and utilities at the center of low-carbon governance. There is a potential for energy issues to become a central part of local and regional spatial strategies (Hodson and Marvin, 2012). Rutherford and Coutard (2014: 1356–1357) note that “while nearly all aspects of urban functioning inherently depend on access to flows and circulations of energy, the production, organization, management, and regulation of these flows are seldom central tasks or competencies of urban actors and local authorities.” Thus, there is a need to upskill and embed technical and economic expertise alongside contextual knowledge about how energy networks are situated in particular places. The examples described in the previous section show how this is changing through the development of arenas for local expertise to integrate spatial and energy logics. In sum, a focus on the production of urban energy landscapes requires close attention to contextual dynamics, institutional arrangements, and the materiality of infrastructure such as heat networks.

Finally, heat networks hint towards the potential for more visible connections between energy services and the built environment. They suggest that energy transitions not only involve changes in urban processes, but also have significant implications on urban form. We can imagine a future urban landscape that is dense, mixed use, and littered with localized energy centers and storage vessels. These features provide visible evidence of a locality’s commitment to low-carbon goals while also making relations between energy and people more visible (Bulkeley, et al., 2014; Rohracher and Spath, 2014). By revealing the material and physical aspects of energy systems, we can begin to develop a socio-technical perspective on sustainable urban transitions.
and a better understanding of how the material, social, and political are implicated in the pursuit of low-carbon futures. The convergence of low carbon urban development and energy system transitions provides an opportunity for urban studies to rethink our relationship with energy while simultaneously reworking the form and function of our cities.

Notes

1. Key policy documents that feature heat networks as central to the UK’s decarbonization strategy include the UK Renewable Energy Strategy, 2009; National Infrastructure Plan, 2011; Overarching National Policy Statement for Energy, 2011; UK Renewable Energy Roadmap, 2011; The Future of Heating: A Strategic Framework for Low Carbon Heat in the UK, 2012; The Future of Heating: Meeting the Challenge, 2013; and Next Steps for UK Heat Policy, 2016.

2. On the history of district heat in the UK, see Russell, 1993; Babus’Haq and Probert, 1996; Weber, 2003; 2014; TCPA/CHPA, 2008; Hawkey, 2009; and Winskel, 2016.

3. A few examples of funding programs for meso scale energy systems in the UK include DEFRA’s Community Energy Program (2002–2005), the Low Carbon Infrastructure Fund (2009–2010), Local Energy Assessment Fund (2011–2012), the Community Energy Saving Program (2009–2012), and the Community Green Deal Program (2013–2014) (see Hawkey, 2012, 2014).

4. These attributes of energy infrastructure are sometimes referred to as contiguity (dispersion/density) and connectivity (Hess, 2004; Bridge et al., 2013).

5. For examples of recent heat network projects, see the websites of The Association of Decentralized Energy (ADE) and Chartered Institute of Building Services Engineers (CIBSE).

6. Formerly the Combined Heat and Power Association (CHPA)

7. The DECC was abolished in July 2016

8. For a summary of the successful local authorities in the funding rounds, see https://www.gov.uk/government/publications/heat-networks-funding-stream-application-and-guidance-pack

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