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Urban Infrastructure Dynamics: market regulation and the shaping of district energy in UK cities

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Abstract

This paper explores the interaction between urban scale energy infrastructure and the regulatory regime which underpins the liberalisation of energy systems. Using the example of district energy in a number of UK cities we outline the ways in which the structure of national electricity markets and the activities of the energy regulator influence and shape the development of low carbon infrastructure in cities. We draw upon recent contributions to the socio-technical systems literature which highlights the role of cities in shaping infrastructure transitions and argue that the influence of sector regulation has been underrepresented and underexplored. Our study points to significant tensions and misalignments between a regulatory regime designed to promote economic efficiencies in incumbent national infrastructure sectors and the development of district energy systems at the urban scale. We propose that regulation needs to evolve from its traditional emphasis on promoting competition and short term efficiencies towards a more dynamic model which is open to alternative logics and low-carbon transition pathways.

Keywords: district energy, socio-technical transitions, energy regulation, urban infrastructure, climate change

Word count: 9,968

1 Introduction

Studies of urban infrastructures and their dynamics have become an increasingly prominent part of sustainability and low-carbon debates. Whether in the energy, water, or mobility sectors, these are complex technical systems which are shaped by a variety of technical and non-technical factors; including technological innovations, institutional changes, business strategies, user practices and ecosystem change (Foxon, 2011). In this paper we pay particular attention to the institutional dimension; focusing on how decision-making in relation to the reconfiguration of urban energy systems is influenced by the regulatory regime governing national energy markets. This seeks to contribute to recent debates on the 'political ecology' of urban infrastructures (Monstadt, 2009), building on work in urban studies and socio-technical systems approaches. We focus on the development and operation of district energy (DE) schemes, otherwise known as combined heat and power with district heating (CHP-DH), which typically involve the generation and distribution of electricity, heat and sometimes cooling within cities. In recent years a number of UK local authorities have sought to install this type of system due to its benefits in terms of fuel efficiency and carbon reductions, but also because of its inherently local character (heat must be distributed locally due to high thermal losses). However, despite its potential efficiency benefits, the diffusion of CHP-DH in the UK has been poor, accounting for only 2% of overall heat demand (PÖYRY, 2009) and 1% of households (Roberts, 2008). In this paper we highlight how the structure and nature of the regulatory institutions which govern the highly liberalised energy sector in the UK have been a particularly influential factor in the evolution of DE, and are continuing to constrain its development, despite the enthusiasm of many local authorities who see this technology as a means to promote climate change and local economic goals.

We situate the study in the wider context of the of the socio-technical transitions literature which seeks to explore the coevolution of actors, institutions and technologies in the reproduction and transformation of large infrastructure systems such as energy supply (Foxon et al., 2010; Verbong and Geels, 2010). Recent contributions to this field have sought to highlight the importance of cities in shaping transition processes, as liberalisation reforms, concerns over the security of centralised provision and the decarbonisation agenda are opening up new spaces of agency at the sub-national level (Bulkeley et al., 2011b; Hodson and Marvin, 2010). To date however the influence of regulation has not been a prominent feature of this literature. Therefore the purpose of this paper is to contribute to these debates by interrogating more closely the role of national regulatory regimes and regulatory agencies in shaping infrastructure transitions at the urban scale. We uncover significant tensions between a regulatory model which privileges market processes as means to reduce the costs of operating incumbent national infrastructures, and the development of local infrastructures which tends to be motivated by a broader set of societal goals than achieving short term efficiencies. We argue for a more dynamic and open model of regulation which does not close down alternative low-carbon pathways.

The paper is structured as follows: In the Section 2, we introduce debates in the socio-technical transitions and urban infrastructure literatures and identify the process of market liberalisation and the application of sector regulation as a missing dimension. Section 3 outlines in more depth the implications of market liberalisation for the structure of infrastructure based sectors and the role that regulatory institutions have played in underpinning this. Focusing on the electricity sector in the UK, we describe what has been termed the 'standard model' of sector regulation which has been applied in liberalised infrastructure sectors as a means of promoting markets and short run operational efficiencies.

Section 4 describes our empirical case study of CHP-DH in the UK, in which we explore ongoing interactions between this 'standard model' of regulation and processes of urban infrastructure development. We identify areas of ongoing conflict between the underlying logics and practices of market based regulation and the development of CHP-DH. Finally, in Section 5, we discuss the implications for understanding the process of market liberalisation and the role of the national regulator as key elements of the socio-technical regime influencing urban infrastructure development, and propose future avenues for research on the relationship between urban socio-technical systems and the regulation of infrastructure networks.

2 Sector regulation - a missing dimension in socio-technical systems studies

Large scale infrastructure systems, for example in the energy, water, and mobility sectors, help to serve a number of private and social goals, and cover a range of scales from local to national. The centrality of these systems in mediating sustainable and low carbon production and demand side practices has prompted efforts understand how the technical features of infrastructures interact with a wide range of societal factors (Bolton and Foxon, 2011; Foxon et al., 2010; Loorbach et al., 2010; Monstadt, 2009; Nye et al., 2009). This raises issues concerning the compatibility of existing national regulatory regimes governing these infrastructure systems with efforts to introduce more sustainable and low carbon systems at a more local level. In the UK, the national regulatory regime governing energy infrastructures has largely been determined around the goals of privatisation of firms and liberalisation of markets, as discussed in Section 3. Below, we discuss how the national regulatory regime and its regulatory agencies are given insufficient attention as structure and actor, in, firstly,

analysis of socio-technical transitions at the national level, and secondly, analysis of the role of cities in mitigating climate change.

2.1 Socio-technical transitions and the multi-level perspective

Drawing on earlier insights from the historically orientated Large Technical Systems literature (Coutard, 1999; Hughes, 1983; Summerton, 1994), the socio-technical transitions approach uncovers the mechanisms by which large scale infrastructure systems undergo transformative change. Infrastructures are framed as complex socio-technical systems which are embedded in a wider set of regimes - technological, science, user and market, policy and socio-cultural (Geels, 2004). These regimes coalesce and coevolve to form configurations or socio-technical assemblages which provide stability and coordination to the functioning of systems e.g. the provision of energy services. Over time infrastructures develop along relatively predictable pathways as the technical system and its supporting institutions coevolve and reinforce one another. For the case of high carbon energy sectors, Unruh (2000) has characterised the outcome of this process as a 'Techno-Institutional Complex' which 'emerge[s] through synergistic coevolution initiated by technological increasing returns and perpetuated by the emergence of dominant technological, organizational and institutional designs' (p. 826). In a more recent contribution, Foxon (2011) elucidates a broader range of coevolutionary processes which influence transitions in energy systems; pointing to interactions between technologies, business strategies, institutions, user practices and natural ecosystems. Due to the technical scale and complexity of large scale infrastructure systems and the need for significant capital investment in a long lived asset base, it is relatively rare that this lock-in or obduracy is overcome. Adopting a multi-level perspective, the transitions approach proposes that change comes about through the interaction between three levels: *the socio-technical regime* is the dominant mode of organising infrastructure services and is

buttressed by established technologies and institutions. *Niches* on the other hand are less constrained spaces where 'radical innovations are generated' and are 'insulated from 'normal' market selection in the regime, they act as 'incubation rooms' for radical novelties' (Geels, 2002: p.1261). Finally, the *landscape* refers to a broader set of factors which shape and contextualise activity within niches and regimes. This includes 'spatial structures (e.g. urban layouts), political ideologies, societal values, beliefs, concerns, the media landscape and macro-economic trends' (Geels, 2012: p.3). Transitions, or system innovations, which fundamentally alter the nature of the socio-technical configuration are an outcome of interactions between these three levels; for example landscape pressures, such as concerns over climate change, may put pressure on regime structures, in the process creating windows of opportunity for radical innovations to emerge which had previously been confined to niches. Geels and Schot (2007) propose a more detailed typology of such multi-level patterns depending on the timing and nature of interactions between levels, these are termed 'transition pathways'.

Infrastructure regulation has clearly been an important part of the socio-technical regime of highly centralised and high carbon energy systems. In the US, for example, economic regulation was pioneered as a means of giving guaranteed rates of return to investors in high capital cost and long lived assets, while in the UK it has been a key institutional pillar which has enabled the privatisation and liberalisation of previously state controlled monopolies. We note however that political-economic developments such as the liberalisation of infrastructure systems tend to be conceptualised in the transitions literature as a background, macro political or landscape factor, rather than an ongoing process which shapes socio-technical interactions both in terms of reinforcing regime structures and enabling or constraining niche level practices. Within the literature regimes in particular are often framed in overly-structural

terms, as a constraint on change at the niche level, consequently there has not been enough focus on agency at this level and the mechanisms by which lock-in is maintained (Smith et al., 2005; Stenzel and Frenzel, 2008). In an analysis of infrastructure based sectors such as energy, there is therefore a need to open up the analysis of regimes in order to make more visible what are seemingly mundane regime activities such as energy market regulation – market design rules, network codes etc. – and analyse how they influence niche level processes.

2.2 Cities, Climate Change and Infrastructure Networks

In contrast to the national focus of the socio-technical transitions literature, a second literature has focussed on the role of cities in influencing and shaping low carbon transitions, arguing that this has been underexplored and undertheorized in the mainstream transitions literature (Bulkeley et al., 2011b; Coutard and Rutherford, 2011; Hodson and Marvin, 2010; Lawhon and Murphy, 2011; Monstadt, 2009). Since the low-carbon transition has typically been framed in terms of achieving emissions reductions targets set by governments at the national level, and in the context of concerns over national energy security, 'the places within and through which transitions occur have largely been absent from analysis' (Bulkeley et al., 2011a: p.4). Hence, within the dominant national level framing, urban infrastructure systems are 'relatively indistinguishable from the national system of which they are part' (Bulkeley et al., 2011b: p.33).

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 conceptualise socio-technical transition processes and infrastructure governance. In a recent contribution to this journal, Monstadt (2009) has begun to addresses some of the analytical

challenges that this poses by seeking to find common ground between urban studies and socio-technical systems approaches. Focusing on energy, water, wastewater and transport systems, Monstadt highlights that these infrastructure systems are central to issues of sustainability and climate change as they 'mediate resource flows and vitally shape environmental problems in modern societies', and therefore their 'modernization holds important keys to solving socio-ecological problems' (p.1924). He notes however that although 'cities depend very much on the functioning of these infrastructures, they have frequently become invisible and taken for granted - which is why they tend to be ignored unless they fail' (p.1931). Monstadt observes that the literature exploring environmental governance processes and political ecology underemphasise the importance of material infrastructures in influencing socio-ecological interactions within cities, while socio-technical approaches tend not to consider the role of cities and the contested and political nature of alternative transition pathways. Seeking to reconcile these strands of the literature, Monstadt's 'political ecology of urban infrastructures' unpacks the interrelationships between urban, socio-technical, and socio-ecological change, and the role of infrastructure networks in mediating between these processes.

By integrating socio-technical systems approaches and more critical perspectives in urban studies, Monstadt's approach opens up fruitful avenues of research which explore the political shaping of infrastructure and the contested nature of socio-technical transitions in cities. However, Monstadt notes that within the literature; 'the urban dimension of infrastructural restructuring through liberalization and privatization processes, or new technological developments and their impact on urban sustainability have remained underexposed' (p.1924). Although some studies in this vein have focused on the new actor constellations and arenas which are emerging in a liberalised context, in particular focusing

on the role of intermediary organisations (Medd and Marvin, 2008; Moss, 2009) which 'act between the traditional relationships between utilities, regulators, and consumers' (Moss, 2009: p. 1489), there has been little empirical analysis of the role of regulatory agencies as important intermediaries between customers, private actors and government. This is likely to be a key factor in most liberalised energy markets as sector regulation of incumbent centralised infrastructure systems has become deeply embedded at the nation-state level. Therefore, an aspect we will seek to explore in our empirical analysis of DE in the UK is the ways in which infrastructure systems developing at an urban scale operate within this wider regulatory regime.

3 Regulating liberalised energy markets in the UK

In this section we discuss this regulatory regime in more detail, paying particular attention to the UK electricity sector and the role of the energy regulator, Ofgem, in implementing market reforms.

During the post-war period in most industrialised countries, infrastructure systems have tended to develop at the national scale, primarily as a result of a widely held consensus that integrated infrastructures were 'natural monopolies' with centralised decision making being the most effective means of coordinating the expansion and operation of complex large technical systems (Hughes, 1983). In European countries the trend was towards public ownership, while in the US network industries were regulated as integrated natural monopolies. The 'integrated ideal' which emerged was centred on Fordist mass production principles, Keynesian demand side policies, and notions of spatial equality (Graham and Marvin, 2001). As Yeung (2010) describes; there was 'widespread social consensus that the role of the state was that of macroeconomic planning, market stabilisation, the provision of

welfare, and acting as employer of last resort' and 'To fulfill these ambitions, many states expanded their control over major resources, most visibly through ownership of key industries, including public utilities such as gas, electricity, water, telecommunications, and the railways' (p.65-66).

This fundamentally modernist conceptualisation was however challenged and undermined by a combination of the economic slowdown of the 1970s and the emergence of a neo-liberal economic paradigm which questioned the efficiency and political legitimacy of integrated monopolies (Averch and Leland, 1962; Demsetz, 1968; Posner, 1969; Stigler, 1971). Yeung outlines that 'states struggled to influence macroeconomic indicators through direct levers…' and were 'no longer able to employ unilateral, discretionary control via command, necessitating reliance on more arm's length forms of oversight, primarily through the use of rules and standards specified in advance.' (Yeung, 2010: p.67). The resulting process of privatisation and market liberalisation has seen the emergence of what has been termed the 'regulatory state' (Majone, 1994), involving '…the dispersal of capacities and resources relevant to the exercise of power among a wide range of state, non-state and supranational actors' (Scott, 2004: p.145). This has seen the rise in prominence of independent regulatory agencies replacing the state's previous role as a direct service provider (Hood et al., 2001).

Privatisation of the energy infrastructure in the UK occurred as a series of one-off events, mostly in the 1980s and 1990s, the reasons cited for which include raising revenue, reducing the power of unionised labour and a desire by the Thatcher government to create a 'shareholder democracy' (Rutledge, 2010). Liberalisation of energy markets on the other hand has been an evolving process since privatisation with numerous legislative changes occurring designed to implement what has been termed the 'standard model' (Voß and

Bauknecht, 2008) of energy regulation where the ultimate goal has been to move towards a market-led system with minimal regulation. Voß (2007) notes that this model has been applied across a number of sectors as a generic governance framework, initially being deployed in the 1970s in frontrunner countries such as the USA, Chile and the UK, being applied more widely in recent years.

The basic rationale behind this has been that the model of infrastructure governance based on vertical integration and strong public sector influence is inefficient as it leads to over-investment in the capital base and poor asset utilisation. Integrated infrastructures across a number of sectors were restructured so as to pare back the natural monopoly segments and to minimise direct public intervention in their day-to-day operation, with the core networks being subject to access regulation in an effort to reduce barriers to entry and create platforms for a variety of market based interactions to occur. In the case of electricity supply this has enabled wholesale trading and competition between service providers. Due to the 'natural monopoly' tendencies of network bound systems, these markets have had to be consciously designed (Glachant, 2009) and the intellectual underpinnings for this process were firmly rooted in the Austrian and neo-liberal economic theories of Friedman, Von Mises, Hayek and Schumpeter (Helm, 2004: p.59). In the UK context, where the reality of market regulation perhaps most closely resembles the theoretical 'standard model', Mitchell outlines a number of principles which underpin the market-led approach:

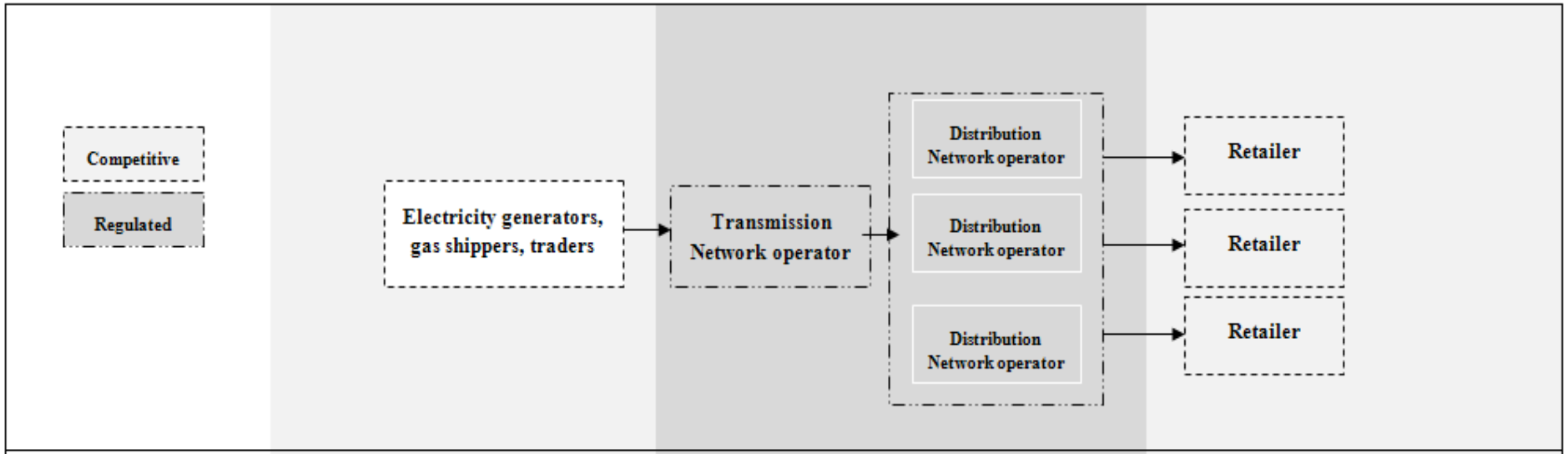
> *"Markets and competition are seen as the most effective way of meeting society's choices; politicians should be legally separated from the regulation and decision-making of industry; … markets should be designed to be technology and fuel blind so that outcomes are not 'picked'; if an outcome is wanted, the policy put in place should mimic markets as far as possible and*

> *should not intervene directly in the market or network rules and incentives …; as far as possible direct regulatory measures should be instituted only in the face of substantial market failures …" (Mitchell, 2008: p.23).*

Independent sector regulators have emerged as key intermediaries between customers, private companies and government, largely by seeking to correct 'market failures', reduce barriers to entry and address information asymmetries (Black, 2010). As the liberalisation process has progressed much regulatory attention has been concentrated on the promotion of competition in the wholesale and retail markets. This was achieved through separating or unbundling the transmission and distribution networks from the competitive areas and regulating these networks to promote network access. Introducing functioning retail markets for energy is generally seen as the panacea for deregulated electricity markets, and despite some setbacks following the Californian energy crisis, it has had strong momentum in the UK. However, despite the desire for minimal regulatory intervention in this model, the regulator exerts significant influence over the transmission and distribution companies who are subject to price controls. As these are seen as largely low-risk and non-competitive activities, the framework has been designed to provide guaranteed rates of return on investment, though there have been strong incentives put in place to reduce operational costs (Bolton and Foxon, 2011). The role and functions of a regulator such as Ofgem across the competitive and regulated components of the energy 'value chain' are outlined in figure 1 below.

While the application of the 'standard model' is generally recognised to have led to significant cost savings, for example through companies improving the marginal efficiency of operating their networks (Jamasb and Pollitt, 2007), in the context of the transition to a low carbon economy, there is a question mark over whether this is an appropriate model for the long term future. For the specific case of the UK energy system, Mitchell (2008) argues that

current institutional arrangements premised on minimum government intervention and a reliance of market mechanisms favours incumbent actors and does not promote innovation, thus reinforcing the current high carbon and centralised pathway. Mitchell likens the current model of energy governance to a ‘band of iron’ which ‘promote[s] narrow, short term, economic considerations which are unlikely to deliver the technical, industrial, institutional and human innovations required’, a form of ‘ideological ‘lock-in’’ which constrains the agency of policy makers and regulators (Mitchell, 2008: p.1).



Some Key regulatory functions	• Monitor wholesale gas and electricity generation market activity against key indicators e.g. market liquidity. • Take action against anti-competitive behaviour and market manipulation. • Monitor and report on energy security.	• Conduct periodic price control reviews which set network connection and use of system charges and control network company revenues. • Ensure non-discriminatory and timely access to the networks. • Incentivise efficiencies and reduce operational costs. • Scrutinise network company business plans and investment decisions.	• Monitor market prices and activity against key indicators e.g. levels of customer switching between suppliers. • Report on developments and conduct investigations into market manipulation and mis-selling. • Administer Renewables Obligation and energy efficiency company obligations.

Figure 1: Key regulatory functions along the energy 'value chain'

4 Energy regulation and city-scale DE schemes in the UK

Following the discussion above it may be asked how city-scale infrastructure responses to climate change are shaped by the wider regulatory environment in which they operate? Through an exploration of CHP-DH systems in a number of UK cities, we now explore some specific interactions between the mode of market regulation outlined above and local energy systems in the UK. This draws from a wider study of the changing regulation and governance of energy distribution networks, both heat and electricity, in the UK (Bolton, 2011). We conducted a number of semi-structured interviews with a range of stakeholders including local authority employees working in the areas of environment and energy services, but also with companies who specialise in the provision of decentralised energy services, an environmental and energy consultant, academics, representatives of CHP-DH industry bodies and policy makers (see Table 1 below).

Interviewees	Number
Local Authority Officials	10
Decentralised Energy Providers	2
Energy Consultants	1
Academics	2
Representatives of Industry	2
National Policy Makers/Advisors[3]	2
Total	**19**

Table 1: Breakdown of interviewees by type

[3] This included one interview with a policy maker in DECC and from the Homes and communities Agency. An interview was conducted with an official at Ofgem in relation to a parallel study of the regulation of electricity distribution networks. This did not directly cover district heating however the interview centered on the issue of the role of regulation in enabling decentralised energy generation.

The interviews were coded according to key themes; including the motivations for local authorities to develop schemes, problems with the financing of CHP-DH and the different ways of organising DE schemes. The sections below present the results of what we saw as one of these key themes; the interaction of national regulation and local DE development. As such the study pays particular attention to how this has influenced decision making at a local level and drew most explicitly from our interviewees with local authority officers who directly engage with the schemes. In order to develop a broader perspective of UK energy policy we also reviewed a large number of policy and regulatory documents relating to the governance of energy infrastructures. Our interviews draw from experiences in a number of cities where DE have been implemented including Southampton, Woking, Nottingham, Sheffield, Aberdeen and Birmingham. Rather than focusing on one particular city, for the purposes of this paper it was decided to look across a number of UK cases to explore the main mechanisms and patterns of interaction between local level responses and the broader regulatory regime.

4.1 Background to CHP-DH in the UK

We begin by giving a brief overview of CHP-DH in the UK which accounts for only 2% of overall heat demand (PÖYRY, 2009) and serves approximately 1% of households (Roberts, 2008). This is in contrast to Nordic countries, e.g. Finland and Denmark, where district heating accounts for 49% and 60% of total heat supply respectively (PÖYRY, 2009). From a historical perspective the work of Stewart Russell provides the most thorough analysis of the reasons why CHP-DH never took a foothold in the UK during the nationalised period (Russell, 1986; Russell, 1993). Russell's work points to a range of factors including the dominance of centralised producer interests, the stripping of local authority power in the energy sector following the post-war nationalisation and a general lack of emphasis on the

potential for end-use efficiencies. Despite a number of attempts to kick-start the industry, government efforts were piecemeal and district heating lacked the supporting policy framework which would allow it to compete against the incumbent gas and electricity suppliers. Also, Russell points to the prioritisation of commercial interests in the energy domain which guarded against the development of energy infrastructure to achieve a wider set of socially orientated goals at the local level.

This story, which is very much characterised by a misalignment between national and local energy policy objectives, was in stark contrast to the much cited case of Denmark where, following the 1970s oil crisis, a 'Heat Law' was introduced in 1979. This placed statutory obligations on municipal authorities to develop local energy plans which identified the locations of significant heat demand. Municipalities were also given the option to oblige buildings located close to a network to connect. Also, at the time heat prices were directly linked to the cost base of developing the infrastructure (IEA, 2008), making it a non-for profit public provision activity. Favourable electricity tariffs – the 'triple tariff' – were also introduced for CHP which allowed them to earn a premium at times of peak system demand, sometimes amounting to three times the off-peak prices (Toke and Fragaki, 2008). The UK has never had this alignment between national and local priorities, but despite these constraints, some schemes were developed which are still in operation today e.g. in Nottingham and Sheffield. There are also a small but growing number of cities which have developed DH schemes in more recent years e.g. Aberdeen, Woking and Birmingham. The reasons for this renewed sense of optimism surrounding DH in the UK are numerous, with some local authorities responding to high fuel poverty rates and others seeing it as an opportunity to use their strategic position by taking a more active role in the energy sector and promoting economic development. Climate change and energy security are also key

contextual factors as councils seek to reduce the carbon footprint of their own activities and deliver greater long term certainty in their energy expenditure by reducing reliance on external energy providers.

At a national level momentum behind DE is also being created by the climate change agenda, this is following the 2008 Climate Change Act which introduced a legally binding carbon emissions reductions target of 80% by 2050 from 1990 levels. The Department for Energy and Climate Change has recently published a heat strategy (DECC, 2012) which highlights the role that DH could play in decarbonising heat demand in dense urban areas where the significant upfront capital investment in the piped infrastructure could be economically justified. Previous work carried out for DECC's Heat and Energy Saving Strategy showed that CHP-DH investments in areas with a high heat density (above 3000 kW/km^2) would be financially viable and could supply approximately 5.5 million properties, accounting for 20% of the UK's overall heat demand (DECC, 2009).

Heat policy in the UK is clearly evolving from the traditional reliance on individual gas boilers, but the extent to which this represents a new window of opportunity for DH, or is part of a similar 'Hype Cycle' (Verbong et al., 2008) seen in previous decades, is uncertain. What is clear is that a necessary component of the success of the CHP-DH niche in the UK will be the alignment between national energy policy and local initiatives, similar to the Danish case. Due to the strong emphasis on energy market regulation in the UK and the strategic role of the regulator in delivering energy policy goals, we argue that this relationship is key and in the following sub-sections we illustrate two areas of interaction.

4.2 Electricity Markets, CHP and Private Wire Networks

The first part of our discussion regarding the interaction between the regulatory regime and DE concerns the operation of CHP plants in the UK's wholesale electricity market. In any DE scheme revenue from the sale of electricity forms a key part of the economic case for investment (Kelly and Pollitt, 2010); as such they need to transact in the national markets for electricity which were introduced following the restructuring of the electricity supply industry. In a number of cases (Woking, Aberdeen, Southampton) we have observed that due to the high transaction costs faced by small scale generators of operating in the national markets, the operators have decided to sell electricity locally to designated customers via private networks as a means of increasing revenues from electricity sales. In the sections below we outline the reasons behind this.

The national wholesale markets for electricity generators, or the British Electricity Trading Transmission Arrangements (BETTA), are based on a system of bilateral trading which allows generators and retail companies to enter into a variety of short and long term contracts. The System Operator's (SO - National Grid) role is to ensure that there is a real-time balance between supply and demand at the national level by operating the balancing mechanism where, one hour before the end of each trading period, following 'gate closure', they review contracts and then accept or reject any further offers or bids from generators and suppliers. Following this, generators who fail to input the same amount of power they had agreed to are penalised and they must pay either the 'system buy price' or the 'system sell price' on the amount of power the fail to generate (Green, 2010). Since the introduction of BETTA there has been much comment on the fact that small scale generators are exposed to additional transaction costs as a result of the structure and functioning of the national electricity markets (Mitchell, 2008; Toke and Fragaki, 2008), along with the costs involved in fulfilling

administrative and credit conditions and registering with the Balance and Settlement Code (BSC). Renewables and CHP generators in particular run the risk of being penalised under the BSC because their output tends to be less predictable (due to intermittency in the case of renewables and the fact that most DE schemes prioritise heat rather than electricity demand). Following the introduction of these trading arrangements, a review indicated that in 2001 there was a 44% overall drop in the output of small scale decentralised generators, and for the specific case of CHP, there was a 61% drop (Mitchell, 2008). Kelly and Pollitt (2010) note that 'the market places a premium on predictable and controllable sources of energy with strong incentives for centralised power. However, the benefits of locally produced power, or power with other associated environmental or community benefits are not rewarded' (p.6941).

In an effort to avoid high transaction costs and penalties and to maximise their electricity revenues within the current market and regulatory environment, a number of strategies have been deployed by DE operators:

1. The first option is to transact in the national level wholesale electricity markets via a third party. This can involve the sale of surplus electricity directly to an energy supplier, typically one of the 'big six', who then transact in BETTA. The key disadvantage with this type of approach is that although the electricity is generated on-site, the operator will end up paying a retail margin on the electricity it uses.
2. The second option is to sell the power to a number of designated customers within the locality. In the case of Leicester excess electricity 'is transmitted through the local distribution network to 17 nominated sites owned by the Council' (Ofgem, 2007b). However, the operator must bear the costs of using the public distribution network, and prior to the introduction in 2010 of a Common Distribution Charging

Methodology across all networks (Ofgem, 2009b), this would not have been cost reflexive, making the distribution of electricity over short distances extremely expensive.

3. An alternative to this is to employ a consolidator to act on behalf of the council or local energy services company. In Aberdeen, for example, electricity is sold to a consolidator who supplies a number of local customers (Ofgem, 2007b) but also pools the output of a number of such generators to trade in the ancillary services market operated centrally by the SO. The local supplier then receives a discounted price for its electrical output. In some cases it may be possible for a DE operator to earn additional revenue by flexing its output in response to SO incentives.

With each of these options however, the operator of a scheme does not receive the full retail price for their electricity. The following quote from a local authority energy manager reflects a more general view that, rather than transact in the national wholesale market in the various ways described above, these revenues should be retained and reinvested within the city:

> *"With the CHP scheme, your valuable commodity is electricity generation; your heat is of a lower value in financial terms. So to make it stack up we really needed an arrangement whereby the developer could sell the electricity and the benefit of that comes back into the city … for the benefit of the people" (Interview – Local Authority)*

In part as a response to these issues, a small number of schemes in the UK have invested in private wire electricity networks which connect CHP generators directly to local customers, thus bypassing the national electricity network and wholesale markets. For example, the DE operator in Southampton has laid a 1 mile 33kV cable to the docks, entering into a ten year

power purchase agreement with the port company. In Woking the council owned Energy Services Company - Thamesway Energy - uses both private and public wires to sell electricity to customers located in the town centre. Although the use of private networks brings with it a large degree of investment risk, this form of re-bundling of energy and revenue flows within the city allows operators to get the full retail price for their electrical output.

However, as the next section will explore in more detail, the reintegration of energy systems in some cities, and particularly the development of private wire networks, has not gone uncontested. The following quote is from a consultant primarily employed by private distribution operators, who sees as inefficient private wires which are in competition with the public (but privately owned) networks, reflecting the established view of electricity systems as 'natural monopolies' at a national scale:

> *"I would feel unhappy if genuine private wire systems emerge, that's a sign of some inefficiency somewhere" (Interview – Consultant)*

Similar sentiments are expressed in the following quote from an interview with a local authority energy manager who emphasised the emerging trade-off between 'optimising' a national energy infrastructure - the majority of which was constructed during the period of public ownership – and efforts to 'optimise' local infrastructure systems in an unfavourable regulatory environment:

> *It also strikes me as being totally daft to replicate the grid system that is already there by putting in another private wire system…We paid for the bloody thing in the first place and yet we have to pay to use it, there seems to be something perverse about it. Having said that, that is the reality. We put*

another set of private wire on a very short stretch of wire adjoining … that building that we are serving directly with electricity" (Interview – Local Authority)

Such forms of 'off-grid' development (Coutard and Rutherford, 2011) and re-bundling are not only prompted by efforts to maximise the revenues accruing from decentralised generation, but also as a means of disconnecting from the wider energy regime and promoting ideas of local autonomy and energy security (Hodson and Marvin, 2011). The next section explores in more detail a number of emerging conflicts as these developments interact with the wider regulatory regime governing the energy sector.

4.3 Energy Regulation, Customer Switching and Infrastructure Investment

A second area of interaction between DE schemes in UK cities and the regulatory regime in the energy sector centres on the conflicts between the mandate of the regulator - to protect the interests of customers by promoting competition – and the need for long term contracts to justify the large upfront capital investment required for district heating infrastructure. As discussed in section 3, in order to facilitate the privatisation and liberalisation of the electricity and gas supply industries, the natural monopoly networks – transmission and distribution - have been separated or unbundled from the areas of the value chain where competition is more feasible – wholesale generation and retail. A central rationale behind this programme of liberalisation and a key concern of the regulator has therefore been to protect the interests of customers, as in a monopoly environment it is perceived that customers run the risk of being exposed to monopoly pricing and a poor quality of service due to a lack of a competitive threat on incumbents (Finger et al., 2005). Since privatisation in the UK the regulator has adopted an approach based on promoting competitive wholesale and retail

markets, in particular emphasising the need for greater levels of customer switching between energy suppliers (Mitchell, 2008; SDC, 2007) as an alternative to more interventionist forms of price regulation. This market based approach is illustrated in the following extract from a strategy document of the regulator Ofgem:

> *"Ofgem's principal statutory objective is to protect the interests of consumers, wherever appropriate by promoting effective competition. Where there is scope to do so, it has been Ofgem's policy to seek appropriate market-based solutions, ensuring equitable treatment of parties, and cost-reflective pricing. In other circumstances the appropriate regulatory policy is one of controlling the exercise of monopoly power" (OFGEM, 2001)*

The relatively small number of CHP-DH schemes in UK cities have been operating in a regulatory vacuum as part of a licence exemption for small scale suppliers who distribute and sell electricity to customers under a certain capacity threshold. The 'Class Exemption Order' (HM Government, 2001) derogates those who supply 'customers up to a maximum of 5 MW of power - of which up to 2.5 MW may be to domestic customers' (DTI, 2004) – this translates to 1-2,000 domestic customers, depending on their end-use efficiency. DE schemes have benefited from this arrangement as it allows them to avoid some of the administrative and transaction costs associated with fulfilling licence obligations and industry codes which may require complex IT systems, specialist staff and entail significant legal costs (Fontenergy, 2009). The exemption allows them to operate as protected niches (Kemp et al., 1998), in some ways removed from the mainstream regulatory process or socio-technical regime. A particularly important implication of this has been the ability of DE operators to enter into longer term contracts with customers, thus reducing uncertainty and providing the necessary stability required for infrastructure investment.

A 2007 Ofgem consultation however raised concerns that the proliferation and expansion of DE currently operating under licence exemptions could compromise customer protection and hinder the development of a competitive retail market for energy services. They noted that 'the development of larger-scale district and city-wide DE projects that fall outside of the 2001 Class Exemption Order … will need to be licensed' (OFGEM, 2007a: p.1). The consultation document raised a number of concerns regarding how customers connected to these schemes may be unable to switch between suppliers, thus leaving them exposed to the potential for monopoly pricing and poor quality of service. This followed a European court ruling known as the Citiworks case[4] where the legality of private wire has been called into question. The case was brought by a large German utility company, Citiworks AG, against a private wire operator in Leipzig Airport. Citiworks AG successfully argued that the supply monopoly breached German law by not allowing third party access to the distribution system. Following the Citiworks ruling, as part of the EU's Third Energy Package, Article 3(5) of the Internal Market in Electricity Directive stated that: 'Member States shall ensure that the eligible customer is in fact able to switch to a new supplier' (OFGEM, 2007a). This ruling subsequently raised concerns as to the legal status of licence exempt district energy schemes in the UK (Fontenergy, 2008) and proposals to mandate private wire operators to publish tariffs and grant third party access are due to be put before parliament in 2012 as part of the implementation program of the EU directives (DECC, 2010).

These issues point to an emerging conflict between the primary goal of regulation - to protect the interests of customers by enabling customer switching between suppliers (Mitchell, 2008; SDC, 2007) - and the requirement for long term supply contracts to reduce the risk of large

[4] European Court of Justice: Case C-439/06

scale infrastructure investments. The following quote from a local authority sustainability manager illustrates the trade-offs involved:

> *"..you can't afford to plough out millions of pounds into pipes and boilers and whatever if (…) the potential customer is going to turn around and say; 'actually we have changed our mind and we are going to buy it from someone else'. So there are huge challenges there" (Interview – Local Authority)*

This uncertainty brought about by the Citiworks case and the increasing interest being taken by the regulator in city-scale DE may also undermine the sustainability of the CHP-DH niche in the UK. To illustrate, an interviewee from a council owned local energy supply company which has entered into long term contracts with customers raised the possibility that incumbent utilities operating at the national scale may sell energy as a loss leader in order to undermine the viability of the municipal energy company:

> *"The big problem with the Citiworks case and what the government is currently wrestling with is that a massive utility provider could come in and say to my customers 'I will give you free electricity if you sign up to me', and if they do, they can give them free electricity for two years and put me out of business and buy my assets for [a] pound" (Interview – Local Energy Supply Company)*

Following a further consultation in 2008 (OFGEM, 2008) and a final proposal document in 2009 (Ofgem, 2009a), Ofgem have made proposals to 'allow small suppliers to become licensed suppliers in a way that is proportionate to their size and impact, while protecting consumers' rights to switch energy supplier' (Ofgem, 2009a: p.1). A proposed licence

modification – the 'Licence Lite' - would allow DE schemes which expand and begin to exceed exemption limits to operate as licensed suppliers whilst providing 'an option for a derogation from the requirement to be a direct party to the industry codes in the electricity supply licence… as long as alternative arrangements are in place with a third party licensed supplier that is a signatory to the industry codes for the scheme to operate in the competitive market and allow consumers to switch energy supplier' (Ofgem, 2009a: p.1). This removes the obligation to engage in 'wholesale market trading, real time system balancing, retail competition and consumer protections' (*ibid*: p.1) as these services are to be made available by the third party licensed supplier which, in theory, would allow the small scale licensee holder to operate more effectively on the public network.

This solution does not alter the fact that the institutional structure and operation of the national electricity market will tend to favour conventional generators with a predictable output, but it does in theory allow DE operators to get the retail price for their electricity whilst not having to invest in private wires. However, as there is no obligation on the third party licensed supplier to provide the necessary services, it is unclear whether the incumbent energy companies – the 'big six' - will be receptive to these arrangements. It is not surprising therefore that to date no 'Licence Lite' applications have been sought or granted (ARUP, 2011), the only significant activity being an ongoing project initiated by the London Borough of Haringey to investigate potential contractual arrangements between a Licence Lite holder and a potential third party licensed supplier[5].

[5] http://www.haringey4020.org.uk/index/useful-information/lcf_studies/licence_lite.htm

5 Discussion and Conclusions

Our case study of district energy in the context of the liberalised UK energy market highlights the import role that national regulatory institutions and agencies play in shaping urban infrastructure. We have shown how the operation of wholesale electricity markets and an emphasis on customer switching in the retail market both help to maintain lock-in to a socio-technical pathway to which DE in the UK is not particularly well aligned. The mechanisms by which this lock-in occurs and is maintained in a liberalised environment can be quite complex and subtle. Micro-level processes of energy regulation we argue are particularly influential, including the ways in which energy markets are designed and function, rules surrounding business separation and unbundling and how transmission and distribution networks are regulated.

These insights, we argue, can inform wider debates in the literature on socio-technical transitions and urban infrastructure introduced in section 2. Our case study shows that within a multi-level framing of energy transitions market liberalisation is not only a background landscape development, but it is a key component of the socio-technical regime, with regulatory institutions actively maintaining lock-in to the dominant socio-technical pathway, leaving little room for agency beyond techno-economic fixes and supply side solutions. Transitions studies in general needs to be more critical of the ongoing liberalisation of infrastructure systems and the conflict between market-led governance logics and the need for long term transformation which meets a broader set of social goals. Paying closer attention to regulatory models and agencies can be a useful way to interrogate this. A key question for transition studies in confronting liberalisation and the 'standard model' of regulation is how an alternative form of infrastructure regulation can be articulated which

strikes a more appropriate balance between the interests of incumbent infrastructure sectors and fostering more localised processes of learning and innovation.

The study has also shown how an analysis of sector regulation can inform studies of urban infrastructure in liberalised contexts. It has historically been the case that many of the institutions of liberalisation operate at the nation-state level; particularly important has been the emergence of national regulatory agencies that have an influential role in market design and oversight. This role is often less visible when viewed from a city scale, but as the example of CHP-DH illustrates, the ongoing process of liberalisation mediated through the underpinning logics and day-to-day practices of regulation should be incorporated as part of a 'political ecology of urban infrastructures' (Monstadt, 2009). This requires an understanding of the manner in which liberalisation reforms have been implemented in a particular context, along with an understanding of the organisational histories and institutional mandates of the regulatory agencies involved. As we move towards more decentralised energy systems, with cities potentially playing a more prominent role in the transition process, conflicts and tensions between actors and institutions embedded at different scales of the energy system are likely to emerge. The study of regulatory logics and practice in relation to urban socio-technical systems can help to uncover this dynamic and become an important bridge between the dominant national level framing of transitions and studies of urban systems.

This paper only represents a first step towards a more systematic analysis of the influence of national regulatory regimes on urban infrastructure and therefore has its limitations. A next step might be to develop a more in-depth analysis of the similarities and differences across infrastructure sectors, e.g. water and energy, linking to calls for a more systematic analysis of cross-sector interactions of infrastructure systems (Hall et al., 2012; Monstadt, 2009; Moss, 2009). Also, our study primarily focused on the UK, which as discussed in section 2, has

been a strong advocate of the standard market-led regulatory model. Analysing other regulatory contexts which have proved to be more conducive to DE could be informative, for example in Denmark there was a greater degree of government intervention and technology specific support. As evidenced by the Citiworks case, there is an important EU dimension to this as the 3rd Energy Package is implemented and EU energy markets become more closely integrated.

Overall our study has highlighted a clear lack of compatibility between a national regulatory regime, which was primarily designed to reduce the costs of operating an incumbent energy system, and investment in CHP-DH which is a response to a wide range of energy and societal challenges faced by cities. The former is largely based on the logic that markets are the most effective and efficient means of achieving societal goals and has been based on a set of acontextual frameworks, rules and codes which are applied across the energy system in an effort to level the 'playing field' and promote competition. The development of CHP-DH on the other hand has emerged as a very context specific activity which requires significant local level coordination and long-term financial commitment. Squaring this circle and charting a new course for energy regulation will be a significant challenge for future research, but it is clear that a governance framework centered on cost reduction and incumbent infrastructures will be inadequate for the needs of low-carbon niches which do not readily align with the incumbent regime. Our study has highlighted the need for regulation to move away from a one-dimensional focus on markets, to begin to govern the system in a way which empowers local actors and does not close down opportunities for the development of alternative socio-technical visions and pathways.

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