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SUSTAINABLE URBAN ENERGY POLICY

HEAT AND THE CITY

David Hawkey, Janette Webb, Heather Lovell,
David McCrone, Margaret Tingey and Mark Winskel

SUSTAINABLE URBAN ENERGY POLICY

Minimising the most severe risks of climate change means ending societal dependence on fossil fuels, and radically improving the efficiency with which we use all energy sources. Such deliberate transformative change is, however, without precedent.

Sustainable Urban Energy Policy debates the major public issue of developing a sustainable, clean and affordable energy system by adopting a distinctive focus on heating in cities. In this way, the book constructs an original account of clean energy policy, politics and provision, grounded in new empirical data derived from case studies of urban and multi-level governance of sustainable heat and energy saving in the UK and Europe. Offering an original conceptual framework, this study builds on socio-technical studies, economic and urban sociology, human geography, applied economics and policy studies in order to understand energy governance and systemic change in energy provisions.

This book is a valuable resource for students and academics in the areas of Science and Technology Studies, Sociology, Geography (Urban Studies) and Political Economy as well as energy policy makers, social housing providers and energy practitioners.

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Debates about the future of energy systems often focus on electricity, and pay insufficient attention to the energy we use as heat in homes and businesses. This book is an exception. It is a valuable resource for anyone wishing to understand the organisational, economic and policy challenges of implementing more sustainable heat infrastructures in cities.

– Jim Watson, Director, UK Energy Research Centre

Two essential yet under-recognised truths about climate and energy leap out from this thoughtful and timely book. First, that there can be no sustainable energy system without a fundamental shift in the way we heat and cool our buildings and second, that despite its global implications, the battle for climate change will be fought not in the hallowed halls of the United Nations but house by house and street by street in cities around the world.

– Paul Voss, Managing Director, EuroHeat and Power, Brussels.

An original, well-researched and authoritative analysis, characteristic of the authors, and a crucial read for anyone seeking to understand the current provision of heat in the UK. With an unprecedented transformation of the UK energy system occurring, this book provides insights based on practical international experience of the history, cultural differences, political processes and power relations that will drive those changes.

– Mike Colechin, UK Energy Technologies Institute

Conceptually rich and empirically engaging, *Sustainable Urban Energy Policy* opens up the largely taken for granted provision of heat in the city to critical inquiry and provides new insights into the politically and socially contested nature of low carbon transitions. Essential reading for researchers and policy makers alike.

– Harriet Bulkeley, University of Durham, UK

Sustainable Urban Energy Policy provides an excellent critical and comparative analysis of the obduracy of existing heating systems and the remarkable difficulties of transforming these into sustainable heat networks. Although the technologies of sustainable heating are well understood, this book powerfully demonstrates that social and political issues explain why the alternatives are not implemented at scale in the city. If you want to properly understand why more effective intervention is crucial to realise the wider societal and environmental potential of metropolitan wide heat networks then read this book.

– Simon Marvin, Director of the Urban Institute, University of Sheffield, UK

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In Memory of Dr Stewart Russell 1955-2011.
Stewart's collegiality and extensive knowledge of energy policy and politics are greatly missed.

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CONTENTS

FIGURES

TABLES

BOXES

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we hope that we have conveyed some of the insights gathered. Second, thanks go to the many householders at the Wyndford Estate, Glasgow who welcomed us, and our team of interviewers, into their homes, not once but twice, and discussed with us their experiences of old and new heating systems. Third, thanks to the many consulting engineers, finance and accounting and legal experts, small and large scale energy utilities, property developers, trade association executives and community energy practitioners who contributed their considerable knowledge to us, and made time to comment on our draft reports. Our Advisory Board were very helpful in commenting on work in progress and in introducing us to relevant experts. Particular personal thanks to Michael King, independent district energy practitioner; Rebecca Carr and Suzanne Le Miere, Scottish Government; Mike Colechin, UK Energy Technologies Institute; Willie Croft, formerly Cube Housing Association, now Riverclyde Homes; George Kirk, Scottish Power; Michael O'Neill and Ciaran Higgins, formerly Scottish Power, now Craighall Energy; Rufus Ford, Jodie Pittaway and the team at SSE; Robin Wiltshire, BRE. We also wish to thank Tim Rotheray and colleagues at the UK Combined Heat and Power Association, now the Association for Decentralised Energy, for their assistance in accessing members, industry briefings and professional events.

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The flaws in the book are of course ours alone.

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PART I

Overview

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1

INTRODUCTION

Current heating provisions and climate change risks

At around 6am on a typical winter's morning in the cities and urban centres of Europe, many households are just beginning to wake up and innumerable timer controls automatically activate their building's heating system. In British cities, the burners in millions of gas central heating boilers will fire, heating water which passes through a closed-loop radiator system, actively circulated by an electric pump. In other countries, the heat may be provided in the form of hot water piped from an underground network, and heated by one or more large boilers, combined heat and power engines or electric pumps. The process is orchestrated both with the daily routines of the city's inhabitants, and with a dizzyingly vast array of physical objects from heat sources, to distribution networks, pumps, wires, meters and computing equipment. In Britain, for example, a gas distribution grid extends to some 275,000km of pipes. This network is in turn supplied by gas from a unified gas transmission system which incorporates over 6,000km of pipework and distributes gas extracted from the North Sea, piped under the sea from other European countries, and shipped (in liquefied form) from further afield (predominantly from Qatar). The electric motor driving circulation of a building's hot water is likely to be connected to one of the many electricity distribution networks (in Britain these total over 750,000km of underground cables and overhead wires), which in turn take power from high voltage transmission networks, energised predominantly by large power stations which produce electricity mainly from combustion of coal and gas, or from nuclear reactions. Such transmission networks are also increasingly interconnected across European countries.

Our energy systems are however the subject of increasing disquiet: the extensive evidence of climate science shows that reliance on fossil fuels is a major contributor to the disruption of the climate system with significant risk to all forms of life on Earth. The most recent report of the United Nations Intergovernmental Panel on Climate Change (IPCC) (2014) finds that energy intensive urbanisation, industry, commerce, transport and trade, powered by coal and latterly oil and gas, have resulted in rapidly rising emissions of greenhouse gases (GHG), leading to atmospheric concentrations of carbon dioxide, methane and nitrous oxide unprecedented in at least 800,000 years. The associated climate disruption is resulting in increasing severity and frequency of storms, flooding, tidal surges and droughts, with serious damage to public service infrastructures, food and water supplies, and intensifying conflict. Such impacts are expected to worsen, even without further GHG emissions, but at present the global exploitation of energy from fossil fuels continues to increase.

Minimising the most severe risks of climate change means ending societal dependence on fossil fuels, and radically improving the efficiency with which we use all energy sources. Such deliberate transformative change is however without precedent. The logics of global economic development continue to centre on expansion of consumer markets and further urbanisation, which are closely correlated with accelerating energy consumption (Jackson 2009). In addition, powerful interests such as those associated with the transnational oil, gas and coal industries contest the need for radical transformation (Henson 2006; Urry 2014), and inter-governmental commitments to reduce carbon dioxide emissions are under-ambitious in relation to the risks of dangerous climate change (United Nations Environmental Programme (UNEP) 2013). Multiple uncertainties remain over political and public will to redirect the considerable technological and financial resources of advanced capitalist societies to the development of low energy systems, and the dismantling of high carbon economic activity.

Why focus on the interface between sustainable heat and cities?

This book addresses a key aspect of such uncertainties by examining the challenges of developing sustainable heating systems in European cities. Cities are both major producers of GHG emissions, and highly vulnerable to the impacts of resulting climate change. The physical and social fabric of urban societies has itself been shaped by the intensive exploitation of coal, oil and gas. The historical origins of high carbon energy systems are in cities, where concentrations of population and industry were sufficient to support shared systems of provision (Geels 2011; Hughes 1983). Although energy systems have vastly outgrown their territorial origins, cities remain the centre of concentrated demand, and thus are likely to be critical to development of more sustainable energy provisions. Over half the world's population now live in urban areas, and in the more developed regions the proportion is over three quarters (United Nations Department of Social and Economic Affairs 2014). Population concentration is matched by concentration in the use of energy.

Three quarters of global final energy demand are estimated to be located in urban areas; in western Europe the proportion is estimated at over 80 per cent (Grubler and Buettner 2013). Very significant proportions of the energy consumed are for heating and hot water. In the EU, for example, energy used for heating accounts for around half of final consumption (RHC Platform 2011). In the UK it makes up over half of typical household energy bills and produces one third of total carbon emissions (UK Government Department of Energy and Climate Change (DECC) 2012).

Changes to social and technical structures of heating provision in cities would hence have far reaching implications across scales. In a direct sense, the spatial concentration of demand means that urban innovation would have radical consequences for global energy systems and GHG emissions. The density of demand, by virtue of the physical proximity of buildings and numbers of inhabitants, also exercises a material influence on the technologies likely to be viable and socially acceptable. Even at suburban densities in Britain, for example, supplying low carbon heat exclusively from ground source heat pumps would result in the ground freezing in winter (MacKay 2009: 152). The dense built environment, and the mass of urban population, is also likely to mean that technologies such as electric air source heat pumps used at individual building scale would result in higher noise pollution, while technologies such as biomass boilers may result in higher air pollution, as well as increased traffic pollution from fuel deliveries. There are also questions about the governance of urban-scale change and innovation, and the distribution of its costs and benefits; should this be a process mediated by city authorities, planned by central governments, driven by the shareholder priorities of private sector energy utilities, informed by energy users, or some combination of all of these, and how should such decisions be made? The answers are contested, and in the book we discuss the reasons why, and compare the strategies emerging in different European countries and cities.

The relationship between heating systems and cities hence encompasses a far wider range of factors than the measured density of demand and potential technical solutions, highlighting a second set of reasons to focus on the interface between the two. The city is not simply a geographical area with a specific local history and culture, but a complex, dynamic social system, distinguished by a particular history, geography and culture, in turn formed by contestation, struggle and conflict over resources (Amin and Thrift 2002; Bulkeley *et al.* 2010). Although cities can be regarded as territorially structured by collections of buildings, roads, parks, water and sewage systems, they are not characterised solely by territorial, administrative and population boundaries. Their boundaries, and the resources produced within them, are themselves the subject of negotiation and struggles for control between local, regional, national and supra-national governments. In this sense cities are incomplete societies (Le Galès 2002): they have both a socio-spatial existence, and they serve as nodes within global exchange networks, channelling flows of material, energy, finance and expertise, through interactions between local and cosmopolitan actors, organisations and institutions. The complexity and indeterminacy of these processes suggests the value of analysing practice in different places, because this should provide insights into the diversity of future options for cities.

In addition to the scale of energy use for heating in cities, and the complexities of cities as social systems, a third reason for investigating heat and the city is the neglect of this meso-scale of analysis in energy policy. The majority of policy initiatives for energy decarbonisation have so far focused on two ends of the energy system, namely energy inputs and end uses. Action in relation to energy inputs has led to an emphasis on measures to decarbonise centralised electricity generation; heat has been a secondary or residual concern. In the UK, low carbon electricity policies are integrated into market incentives for investment in large scale generation of electricity from low carbon or renewable sources, paid for by electricity consumers (DECC 2011). Actions to reduce the end use demand for energy, and to encourage small scale, local renewable generation have centred on user awareness programmes, incremental improvements in energy efficiency standards for buildings, and incentives for micro-generation. These building-oriented demand reduction models tend to focus on energy users as *individual* households or organisations, and underplay the potential systemic efficiencies of locality-based shared provision, and its contribution to overall demand balancing. The book addresses the significance of this 'missing middle', or meso-scale of action, for sustainable heat policy and its implementation.

The fourth reason to focus on heat and cities is, as introduced above, the relative neglect of low carbon heat as a direct focus in energy policy, and the resulting limited research on options for provision and processes of implementation (Connolly *et al.* 2014; DECC 2013). Reasons for this neglect, and recent developments in heat policies which have sought to address it, are examined in chapters 3 and 4. In part the neglect of heat has stemmed from future visions of energy systems centred on low carbon electricity, which would notionally replace other sources of energy for heat and transport (see for example UK Committee on Climate Change 2008). Heat has also been treated as a residual issue in policy making; for example, UK and Scottish renewable heat targets for 2020 were determined by the gap between the overall renewable energy targets, set by climate change commitments, and the renewable electricity and renewable transport fuel targets. Given the scale of energy used for heat in buildings and European commitments to carbon reduction, which typically translate into zero emissions from buildings by 2050, it is critical to redress the balance in energy policy, placing sustainable heat and energy saving in cities centre stage.

The social science perspective on energy policy and technology for sustainable heating systems

There are some well-established and accessible technical solutions for the creation of more sustainable use of energy for heating. These centre on high standards of building insulation, more efficient technologies, and avoidance of the waste of heat sources from industrial processes including electricity generation.

Such solutions are not however systematically or universally implemented, raising questions about why not, and what types of policy changes might be needed to secure more effective use. With these questions in mind, in Chapter 2 we use an explanatory framework encompassing the social scientific analysis of technology and society to understand why technical-economic assessments of optimal solutions do not necessarily determine what happens in practice. We draw on a range of social science, including the economic models implicated in recent energy market liberalisation, but we rely mainly on social studies of technology and urban studies. This socio-technical perspective characterises energy systems as inextricably and irreducibly social and technical in form. We argue that the development of secure, affordable, low carbon heating systems is a matter of social and political, as well as technical, innovation and change. Theoretical models of technically and economically optimal energy solutions are themselves structured by social values and beliefs; in addition such models are only one component of investment decisions and infrastructure developments. In these terms, energy systems are not the technically rational outcomes of clearly defined policy goals and plans, but are shaped by history, cultural differences, political processes and power relations (Hughes 1983; Pinch and Swedberg 2008).

Social studies of technology and urban societies focus on materiality, the circulation and exchange of valued resources, and the territorial politics of energy. The latter is characterised by interactions between European states, regions and cities, in turn caught up in globalising energy and capital markets. Economic conditions, and hence capacities for innovation, in cities are entwined with, and vulnerable to, changing global commodity and financial markets, with gas in particular a key resource used for heating in many European cities. Hence we explore the interdependencies of technology, markets, organisations and users, and the role of existing arrangements in the routine reproduction, or 'lock-in', of particular energy production and consumption patterns (Hommels 2005; Unruh 2000). Future actions, in other words, depend significantly on the social and technical legacy of past decisions, and the interests of incumbents in protecting the value of sunk investment: 'these technology and fuel choices made years ago in cities create a path dependency that shapes current climate change mitigation and adaptation policymaking efforts' (Hammer 2011: 88). We suggest that the obduracy of current 'dynamically stable' (Grin *et al.* 2010) high carbon socio-technical arrangements is not however immutable. Policy analysis is combined with evidence from practice to explore the struggle over policy formation and regulation, and the mutability of business strategies of incumbent organisations. Using original empirical material from the RC-UK *Heat and the City*[1] social science research project, we aim to contribute to understanding of the challenges and the options available, through insights from practice. We examine political processes, governance and societal dynamics with a view to understanding whose voices are represented, and in what ways, in policy making and in practices of translating policy aspirations into specific provisions.

District heating technologies as a component of sustainable urban energy

The book's focus on city-scale change and innovation for sustainable heat leads us to discussion of policies for district heating, which is a commonly advocated energy and carbon saving measure for urban areas of concentrated demand (see for example Connolly *et al*. 2014; IEA 2014). The frequently used model of an energy efficiency hierarchy suggests that policy should prioritise first the reduction of energy use and elimination of waste, then investment in efficient production and consumption infrastructures, and lastly the development of low carbon and renewable energy sources to serve remaining demand. In this hierarchy, district heating is generally understood as an energy efficient infrastructure, which can also open up the use of low carbon and renewable heat sources likely to be inaccessible at individual building scale. It is expected to contribute to the decarbonisation of heat, as well as energy security and affordability, particularly when used in combination with well-insulated buildings. The comparative role of district heating in European strategies for decarbonisation of heat is considered in Chapter 3, and the recent re-emergence of district heating in UK energy policy is discussed in Chapter 5.

The technical components of a district heating system are conceptually simple: a network of highly insulated underground pipes delivers heating in the form of hot water from one or more large heat sources to multiple buildings in nearby areas. Such systems are agnostic with respect to fuel sources, and in principle therefore contribute to energy security while increasing the potential for accessing low carbon and renewable sources at urban scale. In principle the pipework infrastructure also contributes to affordability, because of its ability to move low value sources of heat to places where heat supply is valued, notably for heating and hot water. Heat networks are operated at a range of temperatures, and with varying degrees of efficiency. New York for example has a high temperature steam-based system, whose leaks are responsible for the iconic images of steam rising from Manhattan streets. Most contemporary networks, and all of those discussed in the book, are used to transport medium temperature hot water. Advocates of a next generation of heat networks, construed as smart thermal grids, suggest that further efficiencies can be made by recovery of low temperature heat sources for residual heat supply to highly insulated buildings, as an integral component of a smart energy system (Lund *et al*. 2014; Wald 2013).

Current district heating infrastructure requires highly insulated pipework and associated civil engineering in urban areas and is capital intensive. Its deployment relies on the potential for realising the long-term advantage to be derived from its ability to distribute heat from low cost, otherwise unusable, sources to serve a significant scale of demand. Its capital intensity hence means that it is most viable in dense areas where capital costs can be shared across large numbers of users over a significant period. Such systems are easier to implement where the lead developer has some control over connection of users. Where district heating has developed in Europe, it is associated with a history of relatively strong local government, able to coordinate development of the network infrastructure with patterns of demand. This may be achieved for example through control over house-building and other urban development programmes. Local authority planning and regulatory powers can be used to restrict the availability of alternative energy sources in areas targeted for district heating, and/or to develop more distributed electricity systems around district energy from combined heat and power (CHP) generators (Gronheit and Gram Mortensen 2003; Raven and Verbong 2007; Russell 1993; Summerton 1992).

In the UK, where the post-war electricity system was organised at a national scale, and where local government power to shape patterns of local demand has been limited since at least the 1970s, very little district heating has developed. This is in spite of two periods of concerted policy, first in the years following the nationalisation of energy in 1945, and again in the late 1970s and early 1980s (Russell 1993). Early UK climate policies also emphasised decentralised energy, conceived as a combination of renewable generation and CHP supplying community-scale heat networks. It was acknowledged, however, that this would be difficult in the context of electricity markets and technologies designed around large scale centralised generation (Department of Trade and Industry 2003). A Community Energy Programme (CEP) offering capital support for CHP and district heating was introduced in 2002, but revealed the difficulties of coordinating multiple potential heat users in what had become liberalised markets. The ambivalence and intermittency of central government policies in relation to district heating are important factors in the character of UK cities' efforts to tackle sustainable heating. Local coordination has to be achieved in an *ad hoc* manner under changeable policy conditions. The implications for development of heat networks are considered, in comparison with the scale and scope efficiencies achieved by earlier European district heating, where developments were more commonly the result of strategic planning, in a framework coordinated between central and local governments.

European energy policies and their significance for the future of heating provisions in cities

During the latter part of the twentieth and early part of the twenty-first century, European energy policies have focused primarily on competitive pricing of supply, and have prioritised development of a single liberalised market across EU states as the central mechanism to secure lowest prices (European Commission 2014). Latterly, however, additional concerns with the mitigation of climate change and the security of energy supply have become more prominent. Wider energy and climate policies shape negotiations over low carbon heat regulatory strategies, but there are differing assessments of the effects of climate and energy security politics on energy policies, and on the translation between policy and practice, in different countries.

Liberalisation and privatisation

Until the 1970s there was a broad consensus in European democracies over the critical role of comprehensive energy, water, communications and transport provisions in securing macro-economic prosperity and welfare. This meant that such infrastructures were widely regarded as assets suited to planned investment and public ownership (Helm 2005). During the 1970s, however, many of the advanced European economies faced interlinked crises over industrial performance, deteriorating public finances and increasing costs of universal welfare provisions. Arguments derived from economic theories of markets as more efficient than states as a means of resolving societal problems gained ground in mainstream politics. These coalesced around neo-liberal political-economic advocacy of the extension of markets as a means of promoting competitive use of resources, and introducing profit maximisation as a motivation for efficiency and cost control (Crouch 2011).

Energy liberalisation was one of the measures promoted from the 1990s onwards under principles for creation of a single European market to encourage competitive pricing. Electricity Market Directives shaped the changes, with a focus on short-term cost reduction, during a period of surplus generation capacity. At the time, there was little concern over the future security of energy supply, and climate change was less prominent on the political agenda. In order to stimulate competition, new regulatory principles required the disaggregation of transmission and distribution of energy from generation and retail. These principles have however been differentially implemented in European countries, and the degree and forms of privatisation have been a key source of divergence. In the UK, privatisation of all gas and electricity assets was structured by economic models of cost minimisation for users and guaranteed returns on investments to asset owners (Helm 2010). In other countries, privatisation has been more limited. Liberalisation has nevertheless resulted overall in greater market concentration and consolidation of ownership of utility companies across national borders (Jamasb and Pollitt 2005). This suggests that there has been a decline in local and regional control over heat systems and services. Understanding how the provision of heat in contemporary cities may (or may not) change, and the extent to which city authorities or urban communities remain viable collective actors in energy systems, thus requires attention to policies for liberalisation of energy markets and emerging consequences. The longer-term costs and benefits of liberalisation and privatisation remain contested, and market models remain a work in progress. These debates are discussed in the next chapter, and their implications for the development of sustainable heat in urban settings are threaded through discussion of policy and practice in subsequent chapters 3, 4 and 5.

Enter questions of climate change, energy security and affordability

Energy liberalisation progressed during a period when fossil fuels appeared plentiful and low cost, and when public investment had created an energy infrastructure with plentiful capacity. Incentives were correspondingly geared to 'sweating the assets'. By the end of the twentieth century, however, the context had changed radically; oil and gas demand, and prices, were rising; Europe was becoming increasingly reliant on imported gas; under-investment in infrastructure was becoming evident and the risks of climate change were increasingly salient. These multidimensional issues, often referred to using the neologism of 'the energy trilemma', reflect a perceived three-way tension between security of supply, affordability and climate change mitigation. The liberalisation framework is formally indifferent to climate change, and its suitability to meet radically changed requirements, including the need for long-term planning for a low energy, low carbon system, is contested. The effectiveness and credibility of subsequent policy responses to the perceived trilemma are also subject to question. The aims of energy policy have changed from an emphasis on economic modelling to maximise formal cost efficiency to a more complex set of goals (Winskel and Radcliffe 2014). It is however argued that policy reform has not been effective in reducing GHG emissions, and has been poorly integrated with criteria for energy security (Helm 2015).

Since 2007, the crisis in financial markets and ensuing recession have also made the costs of energy far more prominent both for households and large organisations. On the one hand, this lends impetus to systematic work by large organisations to retrofit public estates for sustained savings and low carbon energy supply. On the other hand, heating and electricity costs are an increasingly significant component of household spending. In the UK, bills have increased by 24 per cent between 2008 and 2012 (DECC 2013), and fuel poverty is increasing. In urban settings, where multi-storey social housing is densely clustered, access to affordable warmth is prompting social landlords, whether housing associations or local authorities, to consider district, or community, heating, alongside better building insulation, as a means to combine carbon reduction with affordability of heat. The replacement of electric storage heating with district heating as part of housing regeneration, and the experiences of householders, are examined in Chapter 9; the implications for new housing developments are discussed in Chapter 10.

The major, intersecting, problems of energy security, affordability and carbon reduction are hence prominent in public debate. Recession and rising energy prices have however been associated with greater uncertainty over European commitments to leadership in climate change mitigation and adaptation, and development of low carbon and sustainable energy. Energy efficiency performance has been slow and incremental, there is relative inertia over targets for clean energy and major subsidies for fossil fuels remain in place (IEA 2011). The EU policy framework for climate change mitigation combines energy efficiency plans with a 'cap and trade' Emissions Trading System (ETS) for heavy industries. In theory the ETS should work as a Europe-wide market mechanism for coordination of the lowest cost approaches to the decarbonisation of energy. In practice, however, an abundant supply of emissions permits has proved to be a source of profitability for large energy generators, without producing commensurate change in technologies (Morris 2014). Internal disunity has also eroded European ambitions (Oberthür and Kelly 2008). In the 2014 announcement of the EU 2030 Framework for

Climate and Energy Policies,[2] there were no binding targets beyond a commitment to 40 per cent reduction in greenhouse gases. An EU-wide target of 27 per cent of energy from renewable sources has been set, without specifying how this will be achieved. EU member states also agreed an indicative, effectively voluntary, target to improve energy efficiency by 25 per cent by 2030. The concentration of asset ownership since liberalisation also implies that future energy systems will be powerfully shaped by large scale incumbent utilities. Consequently, the routes to low carbon transformation of everyday energy use for heating, as well as power, in Europe's cities remain uncertain. Contentious issues of carbon pricing, source fuels, subsidies for low carbon and renewable energy, and economic competiveness interact with decisions on material technologies, their scale and locations. A systemic shift from business as usual for supply of heat may require more radical policy reforms, either to change the rules of the market by further penalising and taxing carbon emissions while incentivising building insulation and the use of waste heat for heat network infrastructure, or to engage directly in planned and coordinated development.

The role of city authorities in strategies for sustainable heating

The energy intensity of urban areas, and the concentration of resources and expertise, creates impetus to treat governments of cities and city regions as one route to innovation in sustainable heat systems. City and regional authorities are supposedly 'unencumbered with the "paralysis" afflicting national governments in responding to resource security and climate change issues' (Hodson and Marvin 2009: 196). City authorities are democratically accountable and exercise powers over planning and regulation, as well as having local knowledge about opportunities and constraints. They are hence well placed to coordinate cross-sector alliances suited to translation of policy into workable local solutions. There are also high expectations about their ability to act as standard bearers for transparency, inclusivity and accountability (Betsill and Bulkeley 2006; Bulkeley and Betsill 2013; Moss 2009). Pioneering city authorities have proceeded to innovate in energy systems, either in relation to their own operations or across their areas, since at least the 1980s (Bulkeley 2010; Morphet and Hams 1994; Shackley *et al.* 2002). In practice, however, the powers and resources available to them to act systematically in relation to energy governance vary across Europe. The UK represents one extreme with strongly centralised control over local authority finances and powers, while city authorities in other European countries exercise considerably greater autonomy. Cities in the UK, although structured by dependence on energy, have very little responsibility for energy production, which is currently dominated by six large corporations, which own the majority of the generation assets, and supply over 95 per cent of retail gas and electricity. In contrast, in many European cities with similar material infrastructure, business structures, ownership and energy supply have remained more diverse. Municipalities and consumer trusts may own or operate local energy plant or distribution networks, as well as energy service companies, either independently or in joint ventures with commercial utilities. These different governance and ownership arrangements are likely to influence understandings and expectations among users regarding the performance of the system, future investment strategy, energy costs and forms of protection against adverse events. They also create different material foundations and resources for heat systems innovation, and confer differences in capacity and capability to act. A degree of convergence in the structures for local governance of energy is however occurring under European liberalised markets: comprehensive local powers over infrastructure and service planning and delivery have typically been reduced, resulting in the need for city governments to act entrepreneurially in pursuit of project finance, building alliances and networks across sectors, organisations and levels of government (Monstadt 2009).

Conversely, the potential for city authorities to act as political entrepreneurs for innovation in sustainable energy is opened up by European Union supra-national governance arrangements. Transnational networks of city authorities, as well as international and state governments, have highlighted the potential for city leadership through non-hierarchical capacity building and sharing of best practice. New modes of action may be devised by coalitions of city and regional institutions, which structure political opportunities at different scales (Le Galès 2002). A number of pioneering city authorities have built on EU exchange programmes to develop cooperation across borders.[3] The European Energy Cities[4] network for example was set up by local authorities to lobby and inform European policies, with the aim of re-localising control over energy as a means of accelerating transition to low carbon and secure supply. Energy Cities works with the EU-sponsored Covenant of Mayors,[5] which has around 5,500 signatories, all of whom pledge to develop a Sustainable Energy Action Plan (SEAP) to exceed the EU 2020 objective of a 20 per cent reduction in greenhouse gas emissions. Within and beyond the EU, further networks link cities around the world; these include the Local Agenda 21 programme, adopted as a voluntary agreement after the 1992 United Nations 'Earth Summit' in Rio de Janeiro, Brazil; the C40 Large Cities Climate Group; the World Mayors Council on Climate Change; and the Cities for Climate Protection programme. ICLEI-Local Governments for Sustainability,[6] formed in 1990, acts as a global network for information and technical support for city-scale governance for sustainability, with European cities forming the majority of members. Each network has somewhat different aims and structures, and a degree of overlapping memberships, but these serve as evidence of the increasing intention and ambition of city authorities to contribute to urban-scale clean and resilient energy systems.

Since the early 2000s a 'second wave' of local activity has developed, incorporating a broader range of actors working in partnership with local government

(Bulkeley 2010). These initiatives are guided by priorities derived from economic regeneration and social justice goals, and their interconnection with political ambitions and local democracy. Evaluation of the impacts of such networks and related developments is, however, limited. A survey of urban climate change experiments in one hundred cities around the world found a common focus on energy-related projects, with municipalities playing a critical role alongside private and community actors (Castán Broto and Bulkeley 2013). The majority of initiatives concerned plans for reduced energy consumption, however, with only a minority investing in new low carbon supply. Even in locally controlled plans there is also frequently a significant gap between planned and actual energy savings and low carbon provision (Hammer 2011). Research has not so far identified any relationship between type of project and particular urban economic and social factors, highlighting the limited state of current knowledge about why and how energy saving and low carbon provision is effected in particular cities. The debates about the governance of urban energy are discussed further in Chapter 2, European comparisons are examined in Chapter 3, case studies of UK cities with plans for more sustainable localised heat provisions are discussed in Chapter 7 and patterns of local engagement in the UK are examined in Chapter 8.

Policies for the decarbonisation of heat are now emerging, although market and regulatory reforms are subject to dissent, and routes to sustainable heat for cities remain uncertain, despite evidence of considerable ambition and activity among European city governments.

Chapter overview

In the following chapters, we examine in more depth the arguments about the governance of social and technical innovation for low carbon heat, and the potential for synergies between sustainability, affordability and security. We treat the ambiguous positioning of heat in energy policy as a valuable means to gain insights into the tensions and dissonances characterising energy systems in an era of liberalised markets, resource constraint and accelerating risks of climate change.

In Chapter 2 we set out the conceptual foundations, drawing together social studies of technology and urban studies to frame contemporary challenges in the development of energy infrastructure in cities. Historical studies emphasise the heterogeneous elements which both shaped, and were reshaped by, the development of large technical systems for mass energy provision, and their interdependence with processes of urbanisation. Contemporary European circumstances are very different from those in which large technical systems first developed. Universal access to public services, including energy, has been challenged by market-oriented policies to differentiate urban populations, often according to attributed ability to pay. Local government powers and resources have generally become more restricted, and cities are expected to compete to attract globally mobile capital for investment in prestigious infrastructure. Such projects are often a critical means to create employment and are likely to be used to bolster the image of the city as economically powerful, technologically 'smart' and at the cutting edge of sustainable innovation. We review theory and empirical analysis of the resulting tensions between liberalised markets, structural obligations on cities to govern through entrepreneurial means, and the exigencies of energy policy goals which imply coordinated and collective action.

In Part II the conceptual framework is applied to the appraisal of policy and politics for sustainable heat. In Chapter 3 the emphasis is on the diversity of European urban heat systems, which stem from the combined impacts of variation in policy, governance, patterns of energy demand and energy resources. The chapter outlines the national and local policies and actions which supported twentieth century development of heat networks in a range of European countries. It compares these with contemporary liberalised policy models for low carbon heat networks in European cities, particularly in Norway and the Netherlands where current development is particularly active. We ask where and why heat networks, as opposed to other forms of heating, play a prominent role in national and city energy policies, and examine consequences and potential for extension to other countries.

Chapter 4 analyses the specific low carbon heat visions and expectations articulated in scenarios of future UK energy systems. The scenarios show the difficulties of setting credible clean energy pathways in a context of high economic, technical and institutional uncertainties. The late 2000s and early 2010s saw the substantial remaking of energy policies, organisations and institutions alongside growing uncertainties over, and reduced political consensus on, energy futures. The envisaged 'official pathway' (articulated by the UK Government and Committee on Climate Change) for the future of heating provision in buildings changed significantly; faith in 'all-electric' scenarios declined and there is increasing belief in the desirability of more mixed heat pathways, with envisaged important contributions from district heating and gas networks.

Chapter 5 builds on this appraisal of heat scenarios by examining the translation of policy visions since the early 2000s into programmes, and discussing their successes and failures in stimulating change in socio-technical systems for heating in urban areas. A wide range of factors are implicated in the slow growth of district heating in the UK, including the intermittency of programmes which target district energy technologies, and the webs of energy policy incentives and constraints within which district heating must develop. Specific programmes have supported the creation of some of the UK's prominent district heating success stories, but these programmes have had limited success in longer-term skills and supply chain development. The range of policies with which proposals for district heating have to interact, coupled with a voluntaristic model of development, mean that provision is often piecemeal and located in specific niches. The chapter considers the strengths and weaknesses of the most recent UK and Scottish policy measures which are seeking 'step changes' in deployment.

In Part III we shift the focus from appraisal of policy to a concern with urban governance and business models, and empirical case studies of local practices. Chapter 6 considers the range of, and rationales for, business models for contemporary district heating networks in relation to economics, finance and risk. It compares the main organisation and ownership structures currently in use, ranging from direct provision by local authorities or social landlords, to locally owned non-profit Energy Service Companies, to joint public-private ventures, and contracts between public and private sector for long-term supply of heat, and possibly electricity. Factors such as risk appraisal and allocation, and their financial implications, shape decisions about business models; these are discussed with reference to particular cases. Finally, the implications for current and future heat network business development are drawn out. Chapter 7 pays particular attention to practices of governance directed at developing such localised provision in liberalised markets, and analyses the uncertain trajectory of district heating in the UK. Using case studies from different cities, and interviews with policy makers and practitioners, the analysis shows that the UK variant of energy market liberalisation, unlike that introduced in European comparators (discussed in Chapter 3), reduces the scope for coordination between local organisations even when they are in the same sector. This means the environmental, social and cost efficiencies derived from larger scale heat networks are not secured, resulting in weaker foundations for new district energy infrastructure. Implications for developing urban-scale sustainable heat in the UK are considered.

Despite the difficulties faced by local project teams, some local authorities are considerably more engaged in sustainable energy developments than others. Chapter 8 examines the factors underpinning such differences. It draws on a new database characterising the forms and extent of local engagement in energy systems for each of the UK's 434 local authority areas, distinguishing between carbon and energy management plans and their implementation. We show that the majority of councils have plans for local energy initiatives; around one third have gone further by investing in retrofit of buildings for energy savings, and/or in some form of decentralised provision. Less than 10 per cent however have made multiple investments. The chapter examines the likely scale of impacts on the energy system if all areas 'levelled up' to the most advanced. We conclude that the contribution is likely to remain small, unless regulatory and market structures are changed to support the implementation of local plans.

Part IV examines the domestic sector and the provision of affordable and sustainable warmth for households. Chapter 9 discusses findings from a longitudinal survey of the impact of a substantial energy 'make-over' on tenants and owner-occupiers on a Glasgow housing estate. It explores the connections between heating systems, paying for energy and social and physical wellbeing, focusing particularly on the meaning of home and the importance of affordable warmth. We compare strategies for coping with cold homes and expensive heating before the housing and heating regeneration work with life since the new system was installed. The findings raise wider questions about whether sustainable cities can be achieved simply by the introduction of low carbon energy systems and better building insulation, or whether structural issues of poverty, under-employment and inequalities also need to be tackled.

In Chapter 10, the focus moves from housing retrofit to new housing development and sustainable heating. In 2006 the UK government set a target for all new housing to be zero carbon within a decade. This chapter explores how the definition of 'zero carbon' has been gradually redefined and made less stringent over time. A surprising consequence of the watering down of the zero carbon definition has been the development of compensating mechanisms ('allowable solutions') which could potentially give an unexpected and significant boost to residential district heating. The chapter draws on this case to assess the politics of attempts to effect radical change in housing and energy infrastructures, and the particular challenges of doing so in highly privatised and liberalised sectors. The case of zero carbon housing demonstrates that despite heat's 'wild card' status in UK policy, there are surprising, and sometimes hidden, opportunities for district heating to present itself as a solution to the multiple policy problems of the energy trilemma of affordability, security and sustainability.

The final chapter draws together the evidence and analysis presented in the book. It evaluates the comparative prospects for sustainable heating for European cities, and the likelihood of greater deployment of district heating in the UK, under current policy and market arrangements. Finally we discuss what would need to change to support coordination between government, business and community actors for accelerated deployment of sustainable urban heating systems, suited to climate change mitigation, energy security and affordability.

Notes

1 RC-UK Heat and the City was a four year research project running between 2010 and 2014, and funded by the UK Research Councils' Energy Programme. www.heatandthecity.org.uk.
2 See ec.europa.eu/clima/policies/2030/index_en.htm.
3 See for example Concerto (www.concertoplus.eu), Cascade (www.cascadecities.eu) and Smart Cities (www.eu-smartcities.eu).
4 See www.energy-cities.eu.
5 See www.covenantofmayors.eu.
6 See www.iclei.org.

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2

SOCIAL STUDIES OF TECHNOLOGY, ENERGY SYSTEMS AND MODERN SOCIETIES

David Hawkey and Janette Webb

Introduction

In this chapter we review the history and contemporary trajectories of energy systems and their governance, with particular reference to the urbanisation of modern societies. We discuss the fundamental interdependence between the social and material order of European cities and the high carbon energy networks, which bring heating, electricity, water and communications to more or less every building: 'Study a city and neglect its sewers and power supplies (as many have) and you miss essential aspects of distributional justice and planning power' (Star 1999: 379). Energy infrastructures are both a material trace of the history of political economy, and the medium for contemporary political and social change (Coutard 1999; Moss 2009). Their history shows the inextricably linked social and technical processes shaping their development, and their corresponding centrality to the growth of liberal-democratic nation states and mass consumer societies.

The extensive and intensive development of energy infrastructures during the twentieth century means that they constitute a critical interface between nature and society, transforming enormous quantities of natural resources into both consumer services and waste materials, often ejected as pollution. They are hence centrally implicated in the exploitation of nature and the destabilising of Earth's climate. Mitigating climate change depends critically on the work of restructuring cities around principles of sustainable production and consumption, including radical transformation of energy systems. With these issues in mind, first we introduce some social science approaches to analysis of energy systems, which emphasise the ways technologies and societies mutually shape each other. We then examine the systemic shift in European societies from a post war era of welfare capitalism to contemporary neo-liberalism in relation to the consequences for energy systems, and for urban government. This sets the scene for discussion in subsequent chapters of the debate about routes to sustainable energy provision, particularly in relation to heat.

Since the 1970s, social studies of technology have moved from a focus on the impacts of technology on society to analysis of the mutual shaping of societies and technologies (MacKenzie and Wajcman 1985). This shift in conceptual understanding is associated with reactions against 'technological determinist' accounts which depict technology as developing according to an internal logic, determined solely by either improvements to existing technologies or developments in science (Russell and Williams 2002). Instead, social scientists argue that the social relations of technology production, diffusion and use shape the technologies developed, and that technologies in turn are implicated in reshaping social conditions.

Drawing insights from the sociology of scientific knowledge, Pinch and Bijker (1984) drew attention to the 'interpretive flexibility' of technologies: different groups interpret the meaning and function of a technology differently and in relation to different objectives. Crucially, different interpretations imply different directions for development of the technology: a given technological artefact may be perceived to have different benefits and defects, and each perspective implies different 'critical problems' (Hughes 1983) to which solutions may be sought. To take one example pertinent to sustainable heating, electricity can be generated from combustion in various ways. A generator may be configured to maximise the amount of electricity produced from a given quantity of fuel, or to produce both electricity and heat, at a useful temperature. The latter approach, Combined Heat and Power (CHP) generally produces less electricity from a given quantity of fuel, but offsets the need to generate heat in some other way. Different actors and organisations pursuing different objectives for electricity generation evaluate the choice between electricity-only and CHP generation differently. But the consequences of different objectives do not stop at the selection of a technology, somehow predefined, say, in a catalogue, but shape the way problems and potential improvements are construed. If the broad objective is maximising the amount of electricity generated, one route to achieve this is to build larger power stations. Power stations sized to meet the demand of multiple population centres may be regarded as beneficial, and the locations chosen for power stations may be influenced by calculated trade-offs between the costs of transporting fuel and the infrastructure required to transmit electricity over long distances. If, in contrast, the broad objective is to minimise the energy resources needed to supply both heat and electricity, then a different set of problems are to the fore: transporting heat long distances is more difficult than transporting electricity; therefore generators need to be located closer to sites of consumption. An engineer working out what size of station would count as optimal will now have to consider the size of settlement into which heat can be supplied.

While this account illustrates how different objectives can shape technologies in different ways, it leaves open questions about how particular objectives come to be pursued by particular individuals, groups or organisations, and how particular objectives may 'winout' over others. These are sociological questions whose answer requires empirical investigation in each case, but some broad themes may be identified. Groups who share similar interpretations of a technology may form alliances to promote their preferred view, and their position in structures of power is important in determining whether they are successful in imposing that interpretation (Klein and Kleinmann 2002; Russell 1986). But different interpretations of a technology, and the positions of different groups in societies, should not be construed as autonomous. Rather they are embedded in a social formation which includes existing technologies and technical systems with which the technology in focus interacts. Increasingly the development of technologies entails the alignment of a wide array of other technical artefacts as well as complex, and increasingly global, networks of governments, businesses, science and engineering expertise, users and investors. Such systems forge interdependencies among human actors and technical artefacts, endowing their suppliers and users with particular capacities, while also stimulating further potential for innovation in response to the new forms of technological affordance, knowledge, interests and political-economic relations. This process is by no means determinate; a successful technological project may not produce the rearrangement of the social landscape which actors envisaged (Russell 1996).

The general point is that social, political and technological trajectories interact in multiple ways: enabling, marginalising or inhibiting the development of particular types of energy systems; affecting the features of specific technical artefacts; shifting the terrain of objectives and problems construed; and changing the capacities of actors to pursue a wide variety of projects. A socio-technical analysis of energy systems is in other words a way of analysing the 'organised complexity' of modern societies, formatted through specialist expertise, institutions and material technologies as well as embodied cultural norms and values (Summerton 1992). In the following sections we examine the historical co-evolution of energy systems and the societies they are part of, focusing on cities in advanced capitalist societies. The picture is necessarily painted with broad brush-strokes, with much important detail glossed over. Our aim is to give a sense of the socio-technical history of energy systems, drawing attention to the co-evolution of technological artefacts, institutions and organisational forms, and the changing objectives and 'critical problems' associated with energy. We use this account to present the context for current efforts to develop sustainable heating in cities, and draw contrasts with the historical development of the massive network systems with which we live.

The interconnecting development of European urban societies and high carbon energy systems

The European transition from feudal to modern industrial societies, with distinctive institutions of nation states, democratic politics and markets was critically dependent on the exploitation of high carbon, energy dense fossil fuels. The enormity of change wrought by the coal powered industrial revolution was evident by the mid-nineteenth century, but this was greatly accelerated by the conversion of coal to electrical power which could be transmitted across much larger areas and used in development of mass production factory systems (Mitchell 2011). The use of coal, rather than wood, for cooking, heating and industrial production meant the end of human dependence on large areas of land for energy production. This was consequential for the geography of human settlement, accelerating the concentration of populations in urban centres whose scale was no longer constrained by the locally available supplies of resources for energy, and where the new factories were located.

Urbanisation was accompanied by the increasing incorporation of city authorities into nation states, which sought to expand empires in order to control supplies of raw materials for industrial production. Cities increasingly served 'as local and regional bases for putting national policies into practice and for legitimizing a form of territorial management by the state' (Le Galès 2002: 75–76). Urban populations disaffected by the inequalities of wage labour and concentrations of urban squalor in newly industrialised societies in turn formed political movements, themselves enabled by the patterns of collective life associated with 'the flow of unprecedented quantities of non-renewable stores of carbon' (Mitchell 2011: 18).

The development of urban infrastructure was an important site for the emergence of changed relations between central and local governments and for the legitimacy of government at each level (Graham and Marvin 2001). For example, in Britain a need for collective management of urban waste was identified around the middle of the eighteenth century. Partial sewage systems serving local elites in some cities tended to make problems worse by concentrating effluent and dumping it into rivers and watercourses used by other segments of the population. While labour movements and industrialists agreed that this was a public health problem, responsibility for solving it was contested. Municipally led solutions were resisted by local elites unwilling to fund collective public health systems from local taxation, and central government attempts to impose solutions were perceived as encroaching on local autonomy. The compromise that emerged involved central government bolstering the authority of local governments by making the local development of public health infrastructure a statutory requirement; this was enacted towards the end of the eighteenth century with significant impacts on mortality rates (Szreter 1988).

While relationships between local authorities and national governments varied across countries (Heinelt and Hlepas 2006), the planning and management of local systems of collective consumption developed as an important competence of local government. Across Europe municipal investment supported development of clean water, refuse collection, road building, street lighting and fire-fighting services (Le Galès 2002). Interestingly, in the UK early local authority investment in gas and electricity systems was a means of creating revenue to support the financing of further public health improvements (Szreter 1988).

The role of local government in the development of local infrastructure was not, however, uniform across countries, and neither were the infrastructures that developed. Thomas Hughes' (1983) comparison of the early development of electricity networks in different cities is an excellent illustration of how system builders worked to weave new infrastructure into the 'seamless webs' they confronted, incorporating, but not limited to, technology, science, finance, industry, regulation and politics. Here we draw on his accounts of electricity network development between 1880 and 1930 in London and Berlin to discuss how different local conditions shaped emerging infrastructure. In London electricity supply developed as a patchwork of municipal and private undertakings, with 64 small generators and diverse standards of electricity supply (voltage, current and frequency). In Berlin by contrast, electricity was supplied by a single undertaking from six central generators. On various metrics, the system in Berlin was regarded as more efficient (higher per-capita use, less fluctuation in patterns of demand, lower costs per unit of electricity generated). Part of the explanation for these differences derives from patterns of industrial development in the two cities. London was a front-runner in the pre-electrification industrial revolution with its relatively small scale industries; in contrast, industrialisation and electrification developed simultaneously in Berlin, where larger scale manufacturing provided substantial load to the developing system. To many of London's smaller scale industries, electrification was perceived to offer relatively little improvement, and to an electricity enterprise each factory connected would represent a much smaller customer than Berlin's factories.

The techno-economic details of differences between the electricity users in the two cities do not, however, exhaust Hughes' (1983) explanation of differences between the resulting systems. Plans *were* developed in London for an integrated city-wide system built by a private company, but these were politically unacceptable to a wide range of interests from municipal socialists to small private undertakings, and attempts to implement them failed. While Berlin had a single municipal government, London had 28 local boroughs, as well as the London County Council, all competing for control and regulation of electricity undertakings. In Berlin the municipality awarded a franchise to a single private enterprise for supply of electricity in the centre of the city; the franchise was renegotiated and the network extended as technology developed. The option for compulsory purchase of the system by the municipality meant productive negotiation between a local government, with capacity to adapt regulation to changing circumstances, and a private operator whose interests extended to the manufacture and financing of electrical equipment for industry. In contrast, struggles for control between private developers, local authorities and county council in London contributed to the resulting patchwork of small systems whose costs were high and efficiencies low by international standards (Hughes 1983).

Different patterns of early electricity network development in Berlin and London illustrate the point that technologies are shaped by a heterogeneous array of factors; in these cases we have focused on different structures of government and associated interests, and different patterns of industry. But the case also illustrates a specific point about network infrastructures. While techno-economic analyses may conclude that large integrated systems have cost and efficiency advantages over a patchwork of fragmented smaller systems, this does not mean that the development of networks able to exploit these scale economies is inevitable. This is an important issue, relevant to contemporary attempts to develop new infrastructure for sustainable heat in cities, and one which recurs throughout this book. Before turning to contemporary conditions for sustainable heating development in cities, however, the next section explores how, in spite of the lack of inevitability, post war societies did in fact construct ubiquitous network energy systems.

Co-evolution of welfare states, cities and high carbon energy systems

In this section we examine the core of political-economic beliefs which governed the mid-twentieth century development of large scale energy networks, under public ownership, in European cities. Common concerns with universal provision and technical standardisation were emerging across Europe and North America, but were situated in relation to diversity in existing provision and again translated into varied patterns of system development, governance and organisation.

The political and economic crises preceding the Second World War, and the spread of state communism in eastern Europe, produced a broad consensus in western European countries about the role of democratic states in macro-economic management, as a means to secure a modern capitalist economy with stable and shared forms of prosperity, and a growing tax base. Citizenship through investment in social security, to provide welfare services and benefits outside the market, was regarded as improving life chances and limiting socially divisive inequalities. Access to paid work and a floor of universal benefits in turn supported expansion of markets through creation of a consumer base for goods and services, in what seemed to be a mutually beneficial interaction between capitalism and democracy (Crouch 2011). For around 30 years, these beliefs, commonly summarised as Keynesian demand management after the British economist John Maynard Keynes, served as the orthodoxy of liberal democracy. The core belief was that state intervention to manage aggregate demand, using public borrowing and investment to stimulate economic activity, could offset the damage caused by the market fluctuations and recessions, regarded as endemic to cycles of capital accumulation. During inflationary periods, the reverse was expected to apply, such that governments would reduce spending and repay debt, reducing aggregate demand and stabilising the economy.

The thesis that social stability and prosperity depended on state management of 'the economy' created the need for an object which could be subjected to such rationalised control: an 'economy' had to be disentangled from the continuous flow of human activities. This was made possible by the new mathematically oriented science of economics, which could be applied to calculation, standardisation and comparative measurement of national productivity and efficiency (Mitchell 2005). One way governments could exercise control over economies was through active participation in certain industries, including the energy industries. As well as affording opportunities for large scale Keynesian investment sustaining aggregate employment and demand, public management of energy was also justified as a site for price control, which came to be regarded as having a role in counteracting inflation (UK Treasury 1961).

The expansion of energy systems was integrated into the role of states in creating conditions for mass production and consumption. On the production side, new factory systems depended on reliable access to energy to power new machinery, with associated reductions in product costs (Geels 2006). The output of these factories required the formation of consumer markets able to absorb the growing volume of standardised products. The planned roll-out of energy networks to housing created the opportunities for home based consumption, using mass produced goods such as fridges, cookers, washing machines, televisions and radios (Graham and Marvin 2001). Standardisation of energy supply eliminated the manufacturing costs of appliances tailored to different systems and maximised the scale of the national market for domestic mass production. Thus alongside transformations in factory products and opportunities to sell them, energy networks were regarded as crucial to raising standards of living (Graham and Marvin 2001).

Public energy provision was further legitimated by economic theory which cast energy systems as natural monopolies; competing providers were regarded as creating wasteful duplication of assets. A *laissez-faire* market, it was argued, would translate theoretical into actual monopoly: incumbent network owners would always have cost advantages over new entrants, due to the relatively low cost of adding new users to an existing network, in comparison with costs of new development. State planning and public ownership then seemed to secure the economic efficiencies of a single system, while avoiding unnecessary duplication of infrastructure, and preventing extraction of monopoly rents (Coutard 1994).

Regulation could protect the perceived benefits of natural monopoly, but monopoly also played a role in the pattern of system development. Monopoly enterprises were able to invest in systems whose capacity was sized to projections of future demand. The risk of this demand not materialising, resulting in stranded assets, was mitigated by regulations which effectively ensured no competitors could 'poach' potential future users. Thus protection of monopoly was regarded as important to achieving long-term cost advantages associated with larger networks and avoiding inefficient patchwork systems such as those observed in London. This development model supported a dynamic of system expansion (Coutard and Rutherford 2011).

Different aspects of the model of comprehensive state planned and managed energy systems were manifest to different degrees in different societies. One axis of variation, central to many of the issues discussed later in this book, is the role of municipal government in coordination and ownership of energy. In the UK, jurisdiction over energy networks was a long running site of contention between private interests, local government and national government through the first half of the twentieth century (UK Government Office for Science 2008). The resulting diversity in energy systems paralleled the fragmented patchwork of electricity systems seen in London (discussed above). In 1920 for example there were nearly 800 undertakings producing and distributing town gas for lighting (Arapostathis *et al.* 2013). Nationalisation and progressive centralisation were prescribed as the solution to a lack of coordination, which was now perceived as resulting in 'irrational' development and poor economic performance (Russell 1993) and UK local government ceased to play a central role in regulating or owning energy systems (Kelly and Pollitt 2010; Russell 2010). While similar arguments underpinned the creation of nationalised energy industries in some other European countries, such as France and Italy, this was not ubiquitous. Municipal organisation, and ownership, of energy remained significant in countries such as Denmark, Finland, Germany, Netherlands, Norway and Sweden, and was evidently not regarded as inefficient.

In sum, the mid-twentieth century formation of liberal-democratic states, committed to managing aggregate demand in market economies geared to social welfare, gave momentum to the development of comprehensive, integrated energy systems. While pursued through different organisational means in different places, the objectives set for energy systems and the ways performance was appraised, problems construed, interventions legitimated, etc. had common bases. Energy infrastructure was crucial to objectives of transforming patterns of production and consumption, and produced a 'super multiplier' effect, whereby public investment in energy infrastructure was considered to yield economic benefits which significantly outweighed costs and supported public finances. Public ownership of networks was legitimated by Keynesian macro-economic analyses, and was believed to solve both the problematic 'irrationalities' of competition and the risks of exploitation associated with private monopolies. States were hence willing to ensure the solvency of energy industries, underwriting the development of universally accessible systems (Coutard 2008). The model of national economic expansion through the factory mass manufacturing system simultaneously shaped the respective roles of local and national government in energy provision, and embedded into societies a material dependence on intensive exploitation of fossil fuels.

The shift to neo-liberal political economy: unbundling of energy and fragmentation of public service governance

Towards the end of the 1960s and through the 1970s, many European economies were caught up in interlinked crises over industrial productivity and profitability, price inflation, and related disputes over pay, rising unemployment and deteriorating public finances. The post war social settlements, geared to a state managed capitalist economy, full employment and universal welfare services, were subject to increased criticism by a resurgent neo-liberal political movement advocating the superiority of the market over the state as a means to address industrial competitiveness, and efficiency in private and public sectors (Crouch 2011).

Publicly owned energy industries became an important focus for these arguments, particularly in the UK, where the intersecting objectives and rationales for state intervention came under pressure during the 1970s. Whereas the post war expansion of energy systems had been integral to the development of mass

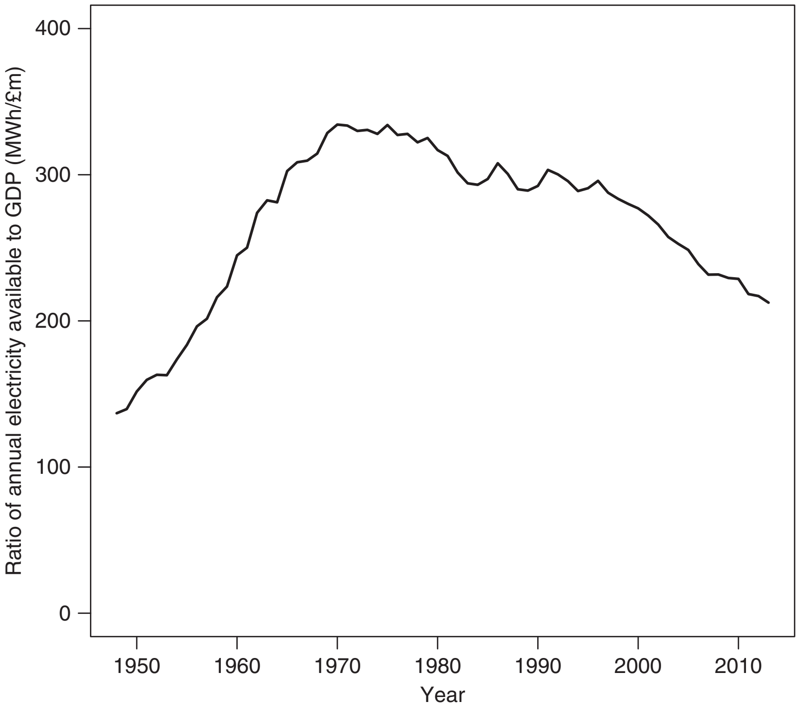

FIGURE 2.1 Evolution of the relationship between combined electricity generation and imports, and Gross Domestic Product in the UK. Source: Data from UK Department of Energy and Climate Change (2013b).

production and consumption, this dynamic appeared to have run its course. For example, in its early period, when the nationalised electricity industry had struggled to keep pace with increasing demand, the growing role of electricity in the national economy was reflected in a rising ratio between electricity production and GDP. As electricity became more central to production and consumption activities the system grew faster than aggregate economic activity (Figure 2.1). From 1970, however, a new dynamic emerged and this ratio began to decline: electricity consumption continued to increase, but at a slower pace than the rest of the economy. A different industrial transformation was under way, with manufacturing in decline, and its replacement by less energy-intense services industries. Although this marked a change in the role of energy system expansion in economic growth, the nationalised industry continued an investment programme driven by projections of continued demand growth. In the context of a renewal of liberal free market theory, the economic efficiency of large nationalised industries was called into question, with charges that managers were more interested in building large asset bases than in serving the public interest (Heald 1980) and, with civil servants, were *over*-forecasting demand and constructing a high cost system with more redundancy than necessary (Helm 2004).

The power of publicly owned corporations to plan and control the development of energy systems hence shifted from being the means by which certain problems could be avoided, to being itself a problematic issue. Energy was not the only domain within which state intervention began to be construed as problematic to the functioning of the economy. Actions by the state to manage aggregate demand, it was argued, resulted in forms of *rigidity* which were reducing opportunities for further growth and capital accumulation:

> There were problems with the rigidity of long-term and large-scale fixed capital investments in mass-production systems that precluded much flexibility of design and presumed stable growth in invariant consumer markets. There were problems of rigidities in labour markets, labour allocation and in labour contracts (especially in the so-called 'monopoly' sector). And any attempt to overcome these rigidities ran into the seemingly immovable force of deeply entrenched working-class power … The rigidities of state commitments also became more serious as entitlement programmes (social security, pension rights, etc.) grew under pressure to keep legitimacy.
>
> *(Harvey 1989: 142)*

Governments had proved reluctant to respond to economic recession and inflationary pressures by imposing politically risky spending cuts, and liberal economic ideas gained ground as these pressures intensified. Throughout the period of welfare state capitalism, theories of the Austrian economic school of thought, associated with Ludwig Von Mises and Friedrich Hayek, had continued to be debated in organisations such as the Institute of Economic Affairs. Amid growing perceptions of dysfunction in the economy, these theories shifted from a marginal position to a dominant position in diagnoses of societies' problems and prescriptions for their solution. Demand management by states, it was now argued, led to governments pursuing political self-interest through use of public spending to buy support, leading to a high tax system and unsustainable levels of public borrowing. The UK approach to nationalisation was depicted as protecting failing and uncompetitive industries for reasons of political expediency rather than economic management, and was used to argue that governments should avoid 'picking winners'. In addition, the expansionary policies of governments were construed as creating 'artificial' demand, distorting productive structures, and generating instability (Wolf 2014). The public sector workforce were charged with pursuing 'producer interests' over those of 'consumer/citizens', and it was suggested this could be changed by subjecting public services to the discipline of markets and competition (Stoker 1999).

Advocates of neo-liberal economic models argued that cost efficiencies depended on the formal separation of politics and economics, with the role of the state depicted as enabling competition through markets, while using monetary policy to control inflation. This required dismantling of forms of national economic protection such as import tariffs, the removal of controls on global mobility of capital, and introduction of regulation where necessary to prevent exploitation of a monopoly position, or to remove attributed 'market barriers' and address 'market failures' (Crouch 2011; Harvey 2005). Price competition, through market-based exchange, was presented as the most efficient means of allocation of scarce resources to maximise public benefit.

By the end of the 1970s, the OECD had moved away from economic demand management policies to advocate privatisation of public utilities such as energy, the introduction of competition mechanisms, outsourcing of public services to private enterprises, and incentives for private finance of public infrastructures under public-private partnership (PPP) business models (Crouch 2011; Grimshaw *et al.* 2002). These generic measures were promoted as a route to improve economic performance in 'mature' capitalist economies by dissolving the rigidities of monopoly and creating flexibility through competition and choice. The measures were expected to reduce the costs of public services, and to maintain low prices for utilities such as energy, thus enabling lower taxation and reduced public borrowing. The core ideas have been subject to diverse interpretations and are associated with a wide array of practice in different countries, depending on the particular political compromises over degrees of privatisation and outsourcing of public services (Lange *et al.* 2013). In no instance however does the advocacy of efficacy of markets over states in governing economic activity equate to a passive form of government. Just as Keynesian economics required the disentanglement of the economy as an object to be managed, the envisaged free market of economic theory makes that objectified economy the target of new state interventions. This time the purpose is to devise structural reforms to bring markets and competition mechanisms into being, across all sectors and categories of goods or services (Du Gay *et al.* 2012). The legitimate role of the state is recast from participating directly in the economy, to shaping the conditions for other actors to compete, with interventions structured around shaping actors' incentives, particularly to correct 'market failures'.

The political dynamics, and indeterminacy, of reshaping public services and energy systems around the theory of efficient markets and competition principles are illustrated here with reference to the UK, which stands out in Europe as a front-runner in extensive dismantling and reform of the planned economy and public ownership of infrastructure. Aspects of neo-liberal reforms tested in the UK have subsequently been emulated in many European countries (Crouch 2011; Le Galès 2002). Core to the recasting of the public sector was the assertion that comprehensive service planning was an inefficient use of resources. Welfare services and the public services which have not been wholly transferred to the private sector (such as, in the UK, health, education and prisons) were correspondingly restructured through market mechanisms, requiring contractual commissioning and outsourcing against tight budgets (Grimshaw *et al.* 2002). The interlinked changes in policies and institutions are characterised by Bowman *et al.* (2014) as giving rise to a 'contract state' (p. 16), where a key feature is the financing of new public buildings, such as schools and hospitals, or other public infrastructure, through a business model defined by its financial viability in capital markets. Whereas earlier public sector service provision used tax revenues and public borrowing for investment, the new approach increasingly seeks to set conditions within which private investors will directly finance public services and infrastructure. Mobilising private capital has thus become crucial to the delivery of many public services, with the dual argument that fiscal pressures mean lack of public funds and that project risk is more appropriately located with capital markets than with taxpayers (Flyvbjerg 2003). Mechanisms to secure this investment require public bodies to make credible commitments to on-going use of, and payment for, the assets financed by private investors. Intense debate over the costs and benefits of different approaches to finance, and the impacts on public services, has ensued.

Neo-liberalism and energy systems

Competition in the energy sector has been promoted throughout EU member states since the 1990s (Helm 2010). Objectives for governance of energy systems shifted from post war projects of raising standards of living, and coordinating the expansion of energy-dependent economic activities, to a greater emphasis on stripping out excessive investment and optimising the economic efficiency of the systems through competition, choice and flexibility. The aim has been to create a single competitive market for energy, with the belief that this would secure lowest prices, but also aid expansion of global markets for capital investment, technology and fuel supply. However, optimum regulatory models to secure competition and asset privatisation were subject to dissent, and moves to dismantle integrated systems and to introduce elements of market exchange have differed, with degree and forms of privatisation a key source of divergence between European countries (Jamasb and Pollitt 2005).

The UK represents one end of the continuum, with full privatisation of the centralised, formerly state owned, energy industries, using the public limited company (plc) structure with shares traded on global stock exchanges. Privatisation of all gas and electricity assets was expected to impose discipline on managers through accountability to shareholders, with rewards tied to profitability derived from successful competition. The basic principles of the model focused on the 'unbundling' of integrated systems through formal separation of generation, transmission, distribution and retail supply, and the introduction of forms of competition via wholesale and retail markets. Where 'natural monopoly' had previously been identified as a beneficial aspect of integrated energy infrastructures to be protected through state regulation, it now began to take on a more negative connotation associated with the parts of an energy system not amenable to competition, namely the distribution and transmission networks (Coutard 1994; Pollitt 2010). Regulatory principles, informed by the theory of market efficiency, were structured by goals of cost minimisation for users and, in the monopoly network sectors, use of a price control formula to incentivise efficiency savings (Helm 2004). Users pay for approved investments in the regulated networks as a component of energy tariffs. The process commenced with the 1980s offer of shares in the British Gas Corporation; electricity privatisation followed in the 1990s.

The timing of privatisation is now regarded as fortuitous in creating a favourable evaluation of the UK model as it took shape in the 1990s: it coincided with an era of plentiful, low cost fuel supplies, in a sector benefiting from the legacy of public investment in a high standard of infrastructure, which could be 'sweated' to keep retail prices down while ensuring high levels of profitability (Helm 2004; Newbery 2012). However, the impact on the UK electricity sector of the reforms went beyond reducing cost through new forms of management and ending what had come to be regarded as overinvestment in the system. The 'dash for gas' which saw almost 10 GW of Combined Cycle Gas Turbine (CCGT) generation developed over a period of five years came as a surprise to many observers (Winskel 2002a). The UK Government's attempt to privatise nuclear power plants ran into serious difficulty, and was widely interpreted as revealing the high costs of the technology which had been masked by the integrated nationalised industry (Winskel 2002b). These changes reinforced perceptions that UK Government and the nationalised industry had failed in its attempts to 'pick winners', and that liberalisation had reconfigured the electricity system in a more economically rational way: the changes 'created a workably competitive industry that was considered an ideal model by many observers, and was influential in stimulating European electricity liberalisation through a sequence of EU Directives' (Newbery 2012: 70).

In addition to technological change, liberalisation of energy industries in Europe has tended to result in market concentration. Inheriting systems with excess capacity, the new competitive enterprises faced few capital investment needs, and innovations in financial markets enabled them to borrow large sums of money, resulting in a spree of transnational mergers and acquisitions (Helm 2004). Ownership structures across Europe are now characterised by a complex pattern of interlocking and partial shareholdings, joint ventures and a high degree of vertical re-integration of generation and supply businesses, with 'more than two-thirds of the European market … now concentrated in the hands of eight large companies' (Jamasb and Pollitt 2005: 26). In the UK, the principle of separating electricity generation from retail to ensure competition in wholesale markets was gradually eroded, resulting in the emergence of a handful of vertically integrated companies with market advantages over independent generators (Thomas 2006). In this context, local energy initiatives such as CHP must either compete against the financial strength and knowledge resources of these transnational firms, or else draw them in as partners or investors by offering secure rates of return competitive with other investment opportunities across the globe.

In European countries where municipal energy systems were well established, liberalisation and privatisation have been associated with diminishing local or regional control over generation and supply of heat and power. Capacity for coordinated public services development, urban planning and cross subsidy between energy and other services is correspondingly reduced (Rutherford and Coutard 2014). Municipal energy enterprises have sometimes been privatised, or restructured as joint public–private enterprises in order to raise revenues or reduce debt. Subsequent mergers and integration into larger trans-European utilities has drawn the global energy investment landscape into local decision making, with contested impacts on costs and configurations of local energy systems. In some German cities these debates have been played out through referendums on re-municipalisation of local energy networks as a means both to re-localise energy profits and to support deployment of low carbon decentralised technologies (Hall *et al.* 2013; Moss *et al.* 2014). In Sweden, debate persists over whether private ownership of district heating networks has resulted in higher prices than municipal ownership (EKAN Gruppen 2009; Rutherford 2008).

Following the shift from planned construction of energy systems to a competitive model of cost minimisation, a new set of objectives began to be institutionalised in European and national energy policies around the end of the twentieth century. Threats to security of energy supplies appeared to loom over Europe with rising oil and gas prices, and growing reliance on imports. In the UK, as in many other countries, a period of asset sweating under liberalisation had left ageing components and electricity networks began to experience failures (Helm 2005). In addition climate change mitigation increasingly became an objective of energy policies as scientific evidence of the impacts of greenhouse gas emissions grew.

These new policy objectives imply forms of reinvestment in energy systems which markets would not produce in the absence of state intervention. Governments have, however, sought to avoid a return to planning energy system development. In part this is because attempts to construct scenarios as a means of calculating 'optimal' routes to decarbonisation result in visions with widely varying technology mixes on the basis of different plausible assumptions (see Chapter 4). In addition, policies which explicitly 'pick winners' risk criticism of economic inefficiency compared with the outcomes of competitive processes (Mitchell 2008). Governments instead seek ways to reshape the incentives understood to drive the decisions of 'market players'. These interventions have taken various forms, including standards and regulation, capital grants, revenue subsidies, differential tax rates, priority 'feed-in' access to markets, and the creation of new markets which trade rights to emit pollutants or impose obligations to deploy renewable energy or energy saving technologies.

The emphasis governments place on holding options open creates coordination challenges as the value or problems associated with a particular investment are inter-dependent with other energy system changes. The issue is particularly salient to the development of sustainable systems of heating. In many cases, envisaged transitions involve changes at building level, in distribution networks and in upstream abstraction and processing of energy resources. Electrification of heat, for example, would have impacts on both the required capacity of electricity distribution networks and the peak demand electricity generators would have to meet. Reducing the role of gas boilers in space heating would have implications for the use and management of existing gas networks, potentially raising costs for remaining users through declining network economies. New and expanding district heating networks require coordinated development of a user base and heat sources of various kinds. As the UK Department of Energy and Climate Change (2013a: 8) frames it, 'the heat question is also the electricity question, the storage question and the infrastructure question'.

Sustainable heat is, therefore, a key policy challenge. Liberalisation of energy systems has established a new context for the coordinated development of systems of heat provision. On the one hand liberalisation is advocated as opening up opportunities for different actors to explore new socio-technical configurations, but on the other it means new institutional means are needed if coordinated development is to be achieved.

Neo-liberalism in urban governance: from planning and welfare to markets and performance management

How might coordination between buildings, infrastructure and energy sources for heating in cities be governed? As discussed above, local government played a key role in establishing and managing local systems of collective consumption in the twentieth century, and city authorities have recently begun to be positioned as key actors in debates about sustainable energy. Political struggle over carbon targets and energy markets at central government level has been accompanied by criticism of incremental and halting progress in relation to energy saving and decarbonisation of the large amounts of energy used for heating and hot water (UK Committee on Climate Change 2013). This combination of factors has directed the attention of states and cities to the potential for urban leadership in energy efficiency, and low carbon decentralised energy, which some argue could also reduce the total costs of systemic change. Urban planning for example could be used to increase energy efficiency in buildings and to match locally available heat from industrial or geo-thermal sources with major heat users through district heating networks. City governments are not only expected by states to use their powers and capacities to enable such developments, but are also positioning themselves as key to future sustainable cities (Bulkeley *et al*. 2015; Rutherford and Coutard 2014).

The development of sustainable urban energy systems is, however, unlikely to be a re-run of the local development of collective goods in the twentieth century. Just as the organisations, institutions and objectives of energy governance have changed, so too have the objectives and mechanisms of local governance. As Rutherford and Coutard (2014: 1365) observe, 'policies, processes and practices at work in cities are inherently intertwined with broader patterns in the spatial, economic and socio-political organisation of societies'. In welfare state capitalism, urban powers over coordinated planning and infrastructure development were central to the idea of the managed market economy, and were used to build the mass production and consumption institutions and infrastructures of the twentieth century. Core beliefs in the application of rational economic measurement to systematic increases in material prosperity, however, also created cities geared to the calculation of comparative productivity and efficiency (Czarniawska 2002), and prepared the ground for a neo-liberal model of urban governance centred on metrics of competitiveness and markets. In the latter, cities are construed as critical to the competitive standing of states in a globalising economy (Florida 2005; Porter 1996), prioritising an economic, rather than welfare, identity, and centring urban governance on mobilising city assets in pursuit of private capital (Harvey 1989; Lapsley *et al.* 2010). This neo-liberal discourse of localism and city/region empowerment, however, is not incompatible with a role for local authorities in securing systems of low carbon energy supply and energy saving. Such systems are framed as new tools of urban competitive advantage to secure resources for 'green growth' in an intensified competition for local access to diminishing natural resources (Hodson and Marvin 2009; While *et al.* 2010). This is presented opportunistically in strategic plans and aspirational visions for sustainable, socially cohesive and prosperous futures, with cities competing for the 'green European capital' or 'Smart City' title, as a device to gain prominence in the urban statistics league tables and hence to secure financial investment in regeneration.

The discourse of city empowerment and entrepreneurialism is, however, combined with new limits to the capacities of city governments to undertake planned and comprehensive programmes of urban renewal or low carbon infrastructure development. The neo-liberal model entails an evolving political commitment to reduced direct public service provision in favour of market contracting, and an open-ended mix of private, public and third sector provision. The attributed rigidities of local authority monopolies are to be dissolved, and replaced with the attributed flexibility and efficiencies of competitive markets. Performance outcomes are then audited using an array of management tools, league tables and cost metrics, which reduce autonomy and intensify workloads (Blanco *et al.* 2014; Le Galès and Scott 2010; Power 1997; Sullivan 2010). In contrast with the period of post war reconstruction, when opportunities were afforded by public programmes for new housing and expansion of infrastructures, urban goals of integrated service provision and common welfare have been superseded by goals of cost reduction, competition and constraints on borrowing. City politicians and officials encounter the operational constraints of cost-driven performance frameworks and declining budgets, in relation to core responsibilities for municipal services. Obligations to use market commissioning and outsourcing, with associated transaction costs of coordination and competition across sectors, organisations and levels of government, mean that local government is increasingly focused on setting conditions for contract delivery and managing networks of providers (Bulkeley and Kern 2006; Monstadt 2007; Rutherford 2008). Knowledge and skills have shifted accordingly from those focused on professional services to those required to engage in intermediary networking and contract negotiation (Grimshaw *et al.* 2002).

Capacity to remake the socio-technical relations of energy for reduced demand and a low carbon system, responsive to urban-scale energy efficiencies and affordability, consequently has to be assembled through entrepreneurial governance, entailing fluid regulation of services and infrastructures through contracts, cross-sector networks and alliances (Hodson *et al.* 2013; Monstadt 2007). A new 'industry' of intermediary actors (consultants, capacity building networks, government agencies and think tanks) with best practice guides, carbon management benchmarking tools and so on has been brought into being and seeks to broker project planning, business modelling and assembly of finance across the conventional boundaries of state, market and civil society (Moss 2009; Rohracher and Späth 2014). The very heterogeneity of such networks means, however, that they are in continual flux, fragmenting and reforming in response to political-economic opportunities and initiatives. Tight timescales and short electoral cycles, with perpetually changing incentives and capital investment frameworks, add to the uncertainties. The abruptly cancelled UK 2002–06 Community Energy Programme, discussed in Chapter 5, is an example of such structural uncertainty and its impacts on decentralised energy and heat developments.

There are therefore questions about whether the strategic plans and visions of smart and sustainable future cities can be implemented through the neo-liberal instruments of market commissioning, private infrastructure finance and intermediary networks, and if so, at what public cost, and under what forms of ownership and control. The move from plans to implementation thus far appears hesitant and uneven, indicating *un*certainty in practice about contemporary urban governance capacity (Bulkeley *et al.* 2014; Castán Broto and Bulkeley 2013; Hawkey *et al.* 2014; Hodson *et al.* 2013; Hodson and Marvin 2009, 2010). Similar patterns of circumscribed project-driven practices, and climate change 'experiments' (Bulkeley *et al.* 2014), are evident across Europe. Constrained budgets and fragmentation across local government activities, mean that city governments struggle to create 'a space through which the urban energy problem can be constituted, articulated and enacted' (Hodson *et al.* 2013: 1408). Comparing low carbon energy initiatives in Greater London, Greater Manchester, Berlin, the Ile de France and Stockholm demonstrates the instability in such projects (Bulkeley *et al.* 2014; Coutard and Rutherford 2010; Hodson *et al.* 2013; Jonas *et al.* 2011; Monstadt 2007; Rutherford 2014). Initiatives are frequently positioned as testing the prospects for new forms of low carbon urbanism, but struggle to gain ground in the context of conflicting policies across different sectors and domains of government. Overall the research findings suggest that while experimentation is possible under new forms of public management, flexibility often entails reversibility of progress in low carbon initiatives. Indeed Bulkeley *et al.* (2014) conclude that such 'experiments become sites of conflict, a means through which new forms of urban circulation can be confined and marginalised, leaving dominant energy regimes relatively intact' (p. 14). There are hence evident constraints on the capacities of city governments for material transformation of high carbon infrastructures.

There is however a risk of over-emphasising the coherence and impermeability, or singularity, of neo-liberalism, and the internal consistency and uniformity of the state, resulting in lack of sensitivity to the political contestation and potential for change (Moss 2014). Few studies have focused centrally on why and how *some* city authorities *are* managing to effect innovations in the relations of energy production and supply, and are using a range of business structures. In Chapter 8 we survey the extent of local authority engagement across the UK, exploring factors which appear to shape the forms this engagement takes. Such interventions result in at least partial reconfiguration of systems of provision, and provide demonstrations of alternatives to the relations and norms of production and supply manifested through large scale utilities (Rohracher and Späth 2014). This redirects attention to the continuing potential for locally scripted variation in innovation capacities and material outcomes in neo-liberal capitalism (Heynen 2014; Keil 2005) and avoids the risk of 'soft forms of economic, institutional and technological determinism' (Coutard and Guy 2007: 720). Such research requires analysis of what Blanco *et al.* (2014) characterise as the logic and practices of the local, where particular projects derive meaning and emotional force from local political and social circumstances and experiences, and an actor network engages with the ambiguities of simultaneous empowerment and control in neo-liberal politics to assemble a degree of agency. In this sense, the neo-liberal political project which highlights the role of cities in responding to climate change and policies for low carbon economy, opens up the potential for local politics, resources and knowledge to mould central government policies to the aspirations and conditions of a locality, 'subverting and resisting them when adaptation [proves] unfeasible, and protecting citizen-led initiatives from incorporation' (Blanco *et al.* 2014: 3139). Investigation of such practices, and their significance for more radical change in energy systems, requires qualitative analysis of local actions, routines, norms and knowledge. In Chapter 7, we therefore explore the connections between the grand narratives of neo-liberalism and its practice-based applications, demonstrated in the laborious and demanding work of legitimating changes in local energy provisions.

Conclusions

Once in place, energy infrastructures in their ubiquity, mundaneness and reliability appear to be stable socio-technical arrangements. Strong mutual dependencies are created between a system and its users, as more social practices coalesce around the availability of large scale, long-lived energy networks and institutions. Users come to depend on the reliable (and affordable) availability of services such as heat and power, and suppliers depend on users to recoup costs and generate surpluses. Summerton (1994) argues that this is however a precarious achievement: the willingness of users to continue using a system, and the extent to which patterns of use conform to the expectations embedded in its design, crucially influence its performance against objectives. Power relations aimed at diminishing the interpretive flexibility, and fixing the meaning, of specific socio-technical infrastructures contribute to processes of stabilisation and relative closure. In energy systems such closure tends however to be partial and temporary. Energy infrastructures and technologies characteristically have lifetimes spanning decades. Indeed, for many utility networks the end point implied by the expression 'lifetime' has not yet been seen. The systems outlive the problems, objectives, debates and organisational patterns which shaped their creation (Helm 2004), but what can be done with them also generally involves compromise between current concerns and the legacies of past objectives and technologies. Social and technical systems are hence interdependent and co-evolving. The historical and contemporary dynamics of energy systems and urban societies show that changes in political, social and economic structures, and associated expertise, lead to changes in what is believed to be optimal in any particular period. This destabilises the idea of a single technically and economically 'correct' route to a sustainable energy system, highlighting indeterminacy and contestation governed both by conflict over goals and contrasting theories about appropriate and effective means.

The extension of high carbon energy systems to the scale of near universal provision in Europe was most intensive during the middle part of the twentieth century, with post war states committed to public investment for material prosperity, seeking to establish and regulate the socio-technical conditions for mass production and consumption. European energy systems were developed as integrated, urban, regional and/or national monopolies, and relied on coordination, and often cross-subsidy, with other public services. Political-economic conditions have since changed significantly, prompted in part by the forms of wealth and knowledge created out of that post war settlement. Energy systems themselves contributed to the changing conditions. Once they were established, and indeed sized in some cases to meet future demand that never materialised, the problems to which public monopoly was a solution receded. Instead of securing the efficiencies of planned integrated infrastructure, objectives shifted to finding ways to operate 'gold plated' systems efficiently and to minimise what became construed as 'distorting' effects of state participation in the economy. Energy privatisation and liberalisation have been important pioneering test cases for the forms of neo-liberalism that emerged from the crises of the 1970s. These reforms, however, have significant consequences for the development of a low carbon energy infrastructure. Current market structures frame this transition as achievable through capital markets or a mix of private and public finance configured in relation to complex and evolving price support mechanisms, state guarantees and long-term concession contracts. Although there are many established low carbon technical systems and energy saving potentials, the direction of change and its governance and financing is contentious and uncertain.

The debate over ways forward is however under way, with an increasingly critical body of evidence about, and analyses of, the emerging climate and energy crisis, and its links to liberalised markets. Such analysis is the necessary starting point for constructive, democratically informed change. In the following chapters we aim to contribute to the analysis through more in-depth examination of European and UK policies and practices for sustainable heat. We set out the rationales for different business models, and examine the relationships to practice in specific cities, and to current levels of local activity in energy systems. We also consider the experiences of low income households in relation to the affordability and effectiveness of a retrofitted district heating system, and the future potential for zero carbon housing. In conclusion, we consider the lessons for contemporary development of sustainable energy for heating in cities.

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PART II

Policy and politics for sustainable heat

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3

EUROPEAN HEAT POLICIES AND PRACTICES

David Hawkey

The previous chapter argued that energy systems developed in the twentieth century co-evolved with a wide range of different institutions and material conditions, with different objectives influencing the ways opportunities and critical problems were identified, and what forms of solution were pursued. While a common theme across Europe was the development of ubiquitous systems under various forms of monopoly, the technologies and resources used show considerable variability, with gas, electricity and district heating networks supplying energy for heating in cities in different countries. These differences reflect combined impacts of variation in a range of factors including governance, policy, path dependency, patterns of energy demand and energy resources. Different legacies condition current challenges in ensuring sustainable energy supplies for heating. For example, district heating networks are 'source agnostic' and can take heat from a wide variety of sources affording cities with extensive networks a range of low carbon options for heating. Gas networks, by contrast, require a combustible gas such as low carbon biogas or hydrogen, restricting options for decarbonisation of existing infrastructure.

In this chapter we explore the development of district heating in European cities looking at interactions between policies and practices in four countries. While the scale of the contribution that heat networks could make to future sustainable energy systems is subject to much debate (see Chapter 4), they are identified in European Union policies, as well as national policies of various countries, as likely to be important components of energy systems capable of meeting long-term energy efficiency and environmental targets. The 2012 EU Energy Efficiency Directive requires member states to assess 'the potential for the application of … efficient district heating and cooling' and to 'adopt policies which encourage due taking into account … of the potential for developing local and regional heat markets' (European Parliament and Council Directive

2012/27/EU: article 14). Accordingly we examine interactions between policy and practice which have brought into being local heat markets, drawing on past and present cases.

Our analysis of past development explores how city-scale heat networks were developed in Sweden and Denmark, countries where district heating is now the dominant form of heat provision (EuroHeat & Power 2013). District heating developed in these countries at similar times and in response to similar issues, particularly high levels of dependence on imported oil and hence exposure to the rapid price rises that resulted from the 1973/74 oil-export embargo in the middle east, and the Iranian revolution in 1979. However, in spite of the similar contexts, district heating developed in different ways in the two countries. Key to both histories are the relationships between local and central government which had quite different characteristics, resulting in different patterns of heat network development. However, in both cases we find that important factors underpinning successful heat network development centre around the positioning of district heating as a solution to critical problems local authorities faced, the capacities of local authorities to organise a large and growing base of district heating users, and supportive national policies around energy taxes, subsidies and finance.

When we turn to contemporary cases (in Norway and the Netherlands) we find similar factors underpinning more recent development of large heat networks, particularly the existence of actors facing problems to which district heating is a solution, and actors endowed with capacities to organise a user base. In these cases, however, problems, solutions and capacities are no longer concentrated in local authorities, but encompass a wider range of actors. Nonetheless, local government continues to play important roles in successful heat network development, albeit in conditions where coordination problems across multiple organisations create new challenges to development of extensive district heating systems.

Municipal energy and district heating

In the wake of the oil crises in the 1970s, several countries explored district heating as a means of making more robust national energy security. However, not all national government visions were successfully translated into local infrastructure (Russell 1996; see also Chapter 5). Drawing on analysis of academic and grey literature, as well as the authors' participation in knowledge exchange events between UK, Danish and Swedish policymakers and practitioners, this section looks at the policies adopted in Denmark and Sweden, and how in practice they supported and shaped the development of district heating in those countries.

Denmark: national model of municipal heat planning

At the time of the 1973/74 oil crises, Denmark imported 99 per cent of its primary energy, principally oil and coal (Lauerson 2011). Heating in Denmark was largely reliant on building-scale oil-fired boilers, though there had been experiments with small heat networks which exploited the difference in price between light oil (which could be burned for heating in individual-building boilers) and heavy oil (which required larger systems) (Lauerson 2011). In the 1960s these initial experiments had tended to focus on peculiar niches formed by clusters of willing organisations. These schemes were a mixture of private and municipal initiatives, and resulted in a degree of indigenous expertise. These small systems developed without significant national direction, but their scaling up to city-wide systems did not happen spontaneously. Crucial to widespread district heating development in Denmark was a new energy planning system instituted by central government.

The 1976 Electricity Supply Act stipulated that all new electricity generators must also supply heat (Chittum and Østergaard 2014). The consequent investment in combined heat and power (CHP) was an important component of Danish heat network development, creating heat sources which would be used to replace individual-building oil-fired boilers with district heating. The 1979 Heat Supply Act in turn created mechanisms to establish heat networks that would absorb this heat, as well as heat from other sources. The Heat Supply Act empowered and required local government to plan systems of local heat provision based on technical analyses of local heat demand and available heat resources (Chittum and Østergaard 2014). A key instrument of the Act was the creation of heat zones. Some zones were allocated as district heating zones (in built-up areas), while in others gas networks would be rolled out to less dense areas. The zoning process was undertaken in collaboration with the Danish Energy Agency, a government agency established in 1975.

A planned approach was advocated as the best means to achieve the lowest cost systemic configuration of energy networks, with the Act envisaging that gas would meet 15 per cent of heat demand and district heating 60 per cent by 2020 (Bertelsen 2011; Dyrelund and Steffensen 2004). Both targets have already been met (EuroHeat & Power 2013). The heat plans drawn up by local authorities were not merely the articulation of a vision or expectation (perhaps guiding other actors' decisions to invest in energy infrastructure), but governed the investment made in the zones (Chittum and Østergaard 2014). The Act gave local authorities strong powers to secure the user base they had identified, for example by requiring buildings (new and existing) to connect to a heat network, and through the power to ban electric heating within identified zones. Building owners were required to pay district heating standing charges even if they took no heat from the system, supporting the predictability of heat network financial models.

The Heat Supply Act thus created significant powers for local authorities to create monopoly heat supply systems. Powers to force connection in district heating areas meant municipalities could share costs among a guaranteed user base, and the planned approach was positioned as achieving lower costs than would competition between systems. Users were protected by state regulations requiring district heating enterprises to operate non-profit business models, using cost-reflective tariffs (which are reported to the Danish Energy Agency) and either reinvesting surpluses into the system or using them to lower bills. Consumers also were also ensured a high degree of control in company governance under structures which still persist. Large heat networks, which account for about half of district heating, tend to be run as municipal companies. In these cases users are represented via municipal government. Smaller networks tend to be run as cooperatives (reflecting a strong tradition of cooperatives in Denmark), are required to hold a seat on the board of directors for consumer representatives, and must give users first refusal to take over the company should it cease trading or be put up for sale (Chittum and Østergaard 2014). Thus powers created by national government to secure heat networks' consumer bases were balanced by price protection and governance participation, drawing on a tradition of strong local government in which civil society is closely integrated.

Alongside the institutionalisation of heat planning, national government supported district heating through energy taxes, grants and (electricity) feed-in tariffs. These have been variously tailored, first to increase price advantages of district heating, and subsequently to shape decisions on fuels and technologies used (particularly, in favour of distributed CHP, away from coal and towards biomass, Lauerson 2011; Sievers *et al.* 2005). Danish district heating businesses are able to mobilise low interest finance for investment as they are perceived as low risk: Danish energy policy support for district heating is perceived to be stable, municipalities (which collect the bulk of income tax) underwrite loans taken on by their own district heating companies and consumer cooperatives, the user base is secure, and both the technologies and the companies are perceived as low risk and efficient (Dyrelund and Steffenson 2004). Thus while the Heat Supply Act was a creation of central government, its success in part depended on the stability and perceived legitimacy of local government. These were (and still are) relatively strong features of Danish local government, as well as several other Northern and Middle European countries. Local authorities have had a strong constitutional role, a high degree of fiscal autonomy, responsibility for allocating a relatively large proportion of public spending, and are perceived as an autonomous level of democratic decision making, while also being closely integrated into national policies and programmes (Heinhelt and Hlepas 2006; Sellers and Kwak 2011).

The development of Danish district heating, then, was enabled by central government Acts under which local government collaborated with central government (in the form of Danish Energy Agency) to plan systems, lock users in place and to absorb the heat that electricity generators were now required to make use of. Non-profit operation and democratic accountability were used to protect users from monopoly exploitation and the perceived strength and stability of the new regime underpinned low financing costs. Under these conditions district heating grew rapidly, from 31 per cent of residential buildings in 1981 to 61 per cent in 2009. Large city networks now integrate a range of heat sources, including coal-, gas- and biomass-fired CHP, energy from waste, and in some cases large scale electric boilers (which absorb surplus electricity when prices are low). Some heat sources are owned by district heating companies, but these companies also buy heat from third parties, enabling use of different heat sources in response to relative costs.

Sweden: local models of municipal heat planning

In Sweden the relationship between central and local government was also important to the development of district heating, but took different forms. Whereas Danish central government instituted a system of heat planning which local authorities were required to adopt, planning of energy systems in Sweden was much more of a locally led process.

District heating development in Sweden was integrated with electricity, sewage and water network infrastructures which municipalities were already responsible for (Ericson 2009). They tended to organise district heating, alongside other public services, including transport, communications and social housing, as arms-length companies able to cross-subsidise each other via umbrella holding companies (Rutherford 2008). The capacity for local government to plan development of buildings and infrastructure in a coordinated fashion was enhanced by strong development planning powers and by the fact that local governments often owned significant proportions of the land within their jurisdictions (Graham and Marvin 2001; Rutherford 2008).

Heat network development began in a handful of cities after the Second World War, and tended to be based around existing oil-fired power stations, retrofitted to operate in CHP mode (Ericson 2009). Aside from these early experiments, the first significant expansion of district heating was prompted by a national house building programme, targeting construction of one million homes between 1965 and 1975, which was delivered by local government. This created a reliable user base, and larger municipalities saw communal heat production (often using heat-only energy centres burning cheap heavy oil) as both lowering energy costs (relative to building-scale light oil-fired boilers) and local pollution (Magnusson 2011). CHP was uncommon during this phase of development, in part because the state-owned electricity company (Vattenfall) used price incentives to discourage local generation in favour of its large scale hydro and nuclear generators (Ericson 2009).

In response to the 1970s oil crises, tackling oil dependence through efficiency and alternative fuels became a central objective of Swedish energy policy. National government support for district heating initially focused on making low cost finance available to housing corporations (65 per cent loan, 35 per cent grant) to support their connection to heat networks. Progress on district heating among smaller municipalities was slow in this period, as the benefits were regarded as uncertain in the context of oil-price uncertainty (Summerton 1992). Rather than imposing requirements for local authorities to develop investment plans for heating (in the model of the Danish 1979 Heat Supply Act) the Swedish government adopted a series of actions which reduced some of this uncertainty and built pressure at local levels to develop heat networks. It adopted a series of Acts beginning in 1977 articulating the envisaged role of municipalities in energy conservation, coupled with low cost, long-term loans for district heating enterprises and local authorities responded to this by, *inter alia*, developing heat networks (Magnusson 2011; Summerton 1992). The second oil crisis in 1978/79 accelerated municipal action.

Sweden's 1977 law required municipalities to develop municipal energy plans, but in contrast with the Danish 1979 Heat Supply Act did not prescribe the form this was to take, and was in practice less forceful. Around a quarter of local authorities still had not developed a plan by 2006, almost three decades later (Ericson 2009). From national government's perspective, central to the purpose of municipal energy planning was demand reduction. However, municipalities responded in different ways reflecting their relative autonomy and the momentum that had built up around some of their district heating enterprises. Thus where municipal companies were facing capacity constraints they were most vigorous in finding ways to reduce energy demand to relieve those issues. Elsewhere municipalities' energy plans were drawn up by their energy companies and effectively functioned as strategies for expansion of their systems (Palm 2006).

Whereas Danish local authorities had power to compel buildings within district heating zones to connect to a network, an equivalent Swedish power was more oblique: buildings within district heating zones could be charged for district heating services even if they refused to connect, but this power was rarely used. Nevertheless, with oil an unattractive heating fuel and electric heating the main alternative to district heating, local authorities were able to manage access to competing systems through their ownership and control over the local electric utilities (Summerton 1992).

Local authorities' energy activities were governed by generic regulations that applied to all local authority businesses. The principal of 'locality' contributed to municipalities' local monopoly powers: local authority businesses were allowed only to operate within the authority's geographical jurisdiction meaning other authorities could not threaten to poach a heat network's target user base. Prevention of competition among municipal companies furthermore fostered collaboration through the Swedish District Heating Association, where information sharing helped raise technical standards and weed out poorly performing technologies (Ericson 2009). The generic principles of equal treatment of citizens and cost-based pricing afforded similar protection to users as those instituted by specific regulation in Denmark.

In contrast with Denmark, then, national government in Sweden played only a minor role in establishing a regime of local heat network planning. Instead, local actors seeking to mitigate the welfare, economic and environmental effects of individual oil-fired boilers drew on existing institutional resources to plan and protect the growth of large scale heat networks. Nonetheless, national government did play an important role in shaping local decisions through its control over energy taxes and a range of subsidies and loans. These have included taxes on oil products introduced in the 1970s, a shift from energy to carbon taxes in the 1990s, exemptions for energy from waste, and incentive schemes to phase out the use of oil and direct electric heating (Ericson 2009). In addition to shaping the relative costs to users of different heating options, these measures have had significant impact on the mix of energy sources used in district heating, effecting a near complete transition away from heavy oil to a diverse range of sources including biomass, industrial surplus heat (particularly from Sweden's extensive forest industries), large scale electric heat pumps and waste incineration.

Contemporary heat network development in liberalised energy markets

As discussed in Chapter 2, the European context for decentralised energy has changed significantly. Neo-liberal theories of the efficient market, and pressure on public budgets, have resulted in moves to create competition in energy markets. Liberalised regulation of energy systems has been guided by the principles of 'unbundling' or dividing control of network infrastructure from control of activities, such as generation and retail, which are positioned as sites of competition between organisations oriented to financial profit. In many cases this has been accompanied by the privatisation of the resulting organisations. Under the neo-liberal separation between politics and the economy, public authorities have far less legitimacy in actively planning and constructing energy systems, instead focusing on establishing and maintaining conditions for other actors to manage energy provision. The models of heat network development in Swedish and Danish cities are thus challenged by liberalisation, given the central role municipal governments played under those models in planning, constructing and operating district heating, as well as controlling relationships between energy networks. In addition, municipal heat network development is further challenged by broader reforms of local government, tending to shift from direct provision of services to an increasing 'commissioning' role. Services previously provided directly by local authorities have been 'unbundled' and outsourced to third parties restricting opportunities for local government to coordinate new heat network development with other local activities under its direct control. Developments in both energy and local government have been variable across Europe, but have had effects even in countries where local government has traditionally integrated energy with provision of other services. Rutherford (2014) describes the consequences of the part-privatisation of the district heating company in Stockholm: while the heat network has continued to decarbonise under national incentives, local control has diminished. One municipal housing corporation is threatening to bypass the system for its new developments, and the city council is claiming the continued and controversial operation of a large coal-fired district heating plant is a matter for the district heating company, not the local authority to decide.

While these developments challenge twentieth century models of municipal control over heat, they do not render the development of heat networks impossible. In this section we examine the development of heat networks after energy liberalisation in countries where heating is dominated by other energy networks: electricity in Norway and gas in the Netherlands. Our analyses draw on government and practitioner documents, interviews with local government and commercial actors in the city cases and a peer-learning exchange with the city of Amsterdam.[1] In these cases we find a more complex diversity in the organisations for whom development of district heating emerges as a solution to a critical problem, and who have capacities to shape local heat markets. However, while the actor networks engaged in district heating development are more complex, local governments continue to play important roles, given their responsibilities for local spatial planning. In the cases we examine political commitments to sustainable energy are an important factor in local authorities choosing to play these roles.

Norway: national framework for liberalised heat planning

Heating in Norway is predominantly dependent on electricity, with over 50 per cent of demand served by either resistive heating or heat pumps. District heating serves a relatively small share of heat demand (6 per cent) but has grown steadily in recent years, increasing more than threefold between 2000 and 2010 (EuroHeat & Power 2013). Most heat network development in Norway has been achieved following the 1990s liberalisation of energy markets.

District heating forms an important part of Norwegian national energy policy. Exposure to fluctuating electricity prices in the Nord Pool trading system, particularly a period of high prices in the winter of 2002–03 when low rainfall limited Scandinavian hydropower production, prompted national government to seek ways of diversifying energy sources. A target for the expansion of district heating was the first item of a 2003 ten-point plan to reduce vulnerability to rainfall. Whereas the extensive electricity network was regarded as enabling diversification of electricity sources (particularly integration of wind power), the absence of heat infrastructure was identified as a barrier to diversification of energy sources for heat (Norwegian Ministry of Petroleum and Energy 2003). District heating enterprises are supported by grants funded from the country's sovereign wealth fund, justified on grounds that the early phases of heat network development may have high average costs relative to the mature systems they are envisaged to grow into (ENOVA 2008).

This financial support has contributed to the recent rapid growth of district heating, but the capacity of local actors to coordinate a base of users around a growing heat network was in place before central government started offering grants. The mechanism for heat planning was established by central government in the 1990 Energy Act, which also set the broader frame for energy liberalisation in Norway. The Act requires operators of DH systems above 10 MW to hold a licence, granted on the basis of detailed development plans, including evidence of integrated social, economic and environmental advantages relative to other options, and of customer commitments to connect (Norwegian Water Resources and Energy Directorate 2009). Licence applicants identify a geographical area within which they would reasonably be able to develop district heating over five to ten years, and, once granted, no competing licence application will be accepted. Licences afford their holders further benefits, including relaxed planning restrictions (as the local authority has the opportunity to comment during the licensing phase) and the option to request local government to adopt policies requiring new buildings to connect. In return, licences impose some restrictions on district heating companies. Some of these are consumer protection measures, such as the requirement to supply heat to subscribers (and obtain a permit if they want to shut the system down), and a price cap set at the equivalent cost of electric heating, the dominant form of heating in Norway. The state also has powers to intervene in heat network development, including the ability to require two heat networks to interconnect and to assume control of a heat network, at no charge, when its licence expires.

The creation of heat planning mechanisms and zoning powers by central government echoes the development model in Denmark. However, whereas the Danish system worked with local government, under Norwegian energy liberalisation licences are not restricted to public authorities. Commercial objectives of licence holders are balanced against social objectives through the licencing procedure. A licence will not be granted unless the applicant can demonstrate that the social costs of the proposed scheme (including capital costs, operating costs and the costs of energy inputs) are lower than the most likely alternative (a combination of electric resistance and oil-fired heating) over a 25 year period. Comparison of future costs is achieved using a low discount rate, set by default at 6.5 per cent per year (in real terms), though applicants can argue for a lower rate on the basis of identified environmental or end-user goals (Norwegian Water Resources and Energy Directorate 2009).

Heat network development in Norway has also been shaped by the regulation of waste incineration, which requires a minimum of 50 per cent energy recovery. The maximum efficiency with which electricity can be generated from waste is usually below 30 per cent, so the minimum requirement effectively forces operators to make use of heat generated (see Chapter 6). Waste incineration is the largest input to Norwegian district heating, tending to supply the base load with a mixture of fossil, renewable and electric sources used for peak demand.

Bergen

Heat network development in Bergen illustrates the practical functioning of national regulation. The municipal waste company (BIR) was granted a waste incineration licence in 1996, and set about solving the problem of finding a use for its heat. Exploration of industrial uses proved unsuccessful, and the company approached an electricity utility, BKK, to collaborate in heat network development. BKK operates the local electricity distribution network, and saw a complementarity between this and the heat network, which would limit growth in electricity demand, thus deferring investment in the electricity network. A joint venture (BKK Varme) was formed in 1997 between the two companies in which BKK exercises overall control through a 51 per cent shareholding.

The new company's first task was to obtain a district heating licence, a process which took two years. The licence application required detailed design of the system, including demonstrable commitments from targeted users to connect.

A hospital was identified as a key load, which would both anchor the system (taking a quarter of the heat) and provide backup/peaking heat, as hospital managers insisted on retaining an independent reserve capacity to meet onsite heat needs. Designing the network was a labour-intensive process as the company lacked data on the heat demand of local buildings, and had to liaise directly with building owners. Through this process they gathered written commitments from building owners to connect to the system. The licencing system stabilised these mutual commitments: prospective users were protected by the regulated price cap, and BKK Varme could be sure an alternative heat network wouldn't be able to recruit its targeted buildings. The company liaised with other local infrastructure developers both to find opportunities to coordinate works (for example, the main heat transmission line was constructed in parallel with a new motorway) and to draw on local insight regarding issues surrounding subterranean infrastructure and working with the local authority. Thus the large volume of heat available from the incinerator and the long time-horizon embedded in the heat network licencing procedure framed detailed planning of the establishment and expansion of the network.

With a licence granted, construction of the network began in January 2000. The initial construction phase was significant, including connection of around 100 GWh/year heat load and construction of the transmission line bringing heat from the incinerator 12 km from the centre of town. This construction phase lasted three and a half years, during which no heat was delivered. Once commissioned the system continued to grow, reaching over 200 GWh delivered per year by 2010 and plans to increase this to 275 GWh/year. At the time limited grant funding was available for district heating so the initiative was funded by owners' equity, and loans from BKK. Protection of the planned expansion under the exclusive area-based licence supported the company's continued sinking of investment into the system as it expanded. The business did not break even until 2010, a decade after construction began (BKK 2010).

The local authority, Bergen Kommune, was not initially a direct participant in development, although it is a major shareholder in both BKK and BIR. From 2007 it adopted a more proactive role, partly because of growing Norwegian political emphasis on climate protection which gave salience to pre-existing local policies, and partly because of the perceived local economic benefits of the rapid development of a large heat network. The Kommune collaborated with BKK Varme in subsequent development to identify sites for new energy centres (based on renewable energy) and has converted major municipal buildings to water-based heating. It has also worked to coordinate extension of the heat network with local development planning. Initially BKK Varme would appraise extension of the network to a new development on the basis of the likely heat demand of that development. Integration with development planning however enables the company to consider the likelihood that additional buildings will be constructed nearby. This often improves the business case for network extension.

In summary, Norwegian state regulation of district heating establishes a framework for long-term development of heat network, protecting users from excessive charges and the licence holder from competing networks. The framework charts a middle course between monopoly and liberalisation by not restricting licences to specific organisations, and retains state oversight through judgements on the social costs of different options and step-in rights. Regulation of waste incineration has meant the establishment of heat networks is a solution to an immediate problem confronted by waste management companies, and while BKK Varme managed to construct a large network without grant funding, the Norwegian government has intervened in the calculus of local financial viability by making grants available. Under the liberalised approach local government is not positioned as a central actor, but experience in Bergen suggests local authorities nonetheless can play important roles in stabilising and expanding heat networks through their role as planning authorities and as owners of a large local estate.

Netherlands: local authority initiatives in liberalised markets

Natural gas was discovered in the Netherlands in the 1950s and rapidly grew to be the dominant energy source for the country. Heating with individual gas-fired boilers is common, and district heating accounts for around 5 per cent of domestic heating systems (EuroHeat & Power 2013). Most district heating developed prior to the liberalisation of the Dutch energy markets, particularly during the 1980s and 1990s when high electricity prices and regulatory and financial support led to significant deployment of gas-fired CHP (most of which, however, served industrial and horticultural heat demand; Hekkert *et al.* 2007). Heat network development had a weak institutional base during this period. While central government established a District Heating Committee and commissioned 50 feasibility studies, only 16 schemes were developed. Projects tended to be led by electricity utilities which, at the time, were usually regional enterprises owned by provinces. Municipalities, most of which owned local gas companies and regarded them as important sources of revenue, tended to oppose development of heat networks (Raven and Verbong 2007).

The cases we discuss below concern the development of heat networks after energy liberalisation meaning both that the forms of monopoly control of the past are now less relevant, but also that the relationship of municipal authorities to gas networks has changed as companies have merged and municipal stakes have been sold. The growing salience of climate change politics also influences municipal activity in the cases we discuss. However, the form that heat network planning takes is not shaped by a framework articulated by national government, but is instead locally negotiated. In this sense the Dutch cases we present parallel the Swedish historical cases discussed above, though the forms of coordination are more complex given the greater number of organisations involved and limits to the control local government can exert over these organisations.

While network planning and development is a locally driven process in the Netherlands, national government has introduced regulation specific to district heating to protect small users from monopoly exploitation. The Dutch parliament began discussing the regulations in 2003, but they took more than a decade to come into force (Netherlands Consumer and Markets Authority 2013; van der Zee 2011) and mirrored policies that were already common across district heating initiatives. Prices are capped by the 'niet meer dan anders' principle (no more than the alternative), and set to ensure heat network customers do not pay more than they would for gas-based heating. The law also regulates other aspects of the relationship between district heating companies and their customers (such as dispute resolution and compensation schedules) and requires companies to separate their heat networks from other activities in their accounts such that profit rates can be monitored (Netherlands Consumer and Markets Authority 2014).

National policy specific to district heating, therefore, focuses primarily on consumer protection in the absence of retail competition. The capacity of local actors to develop heat networks is not directly addressed by national regulation specific to district heating, other than indirectly to the extent such regulations increase confidence among consumers. Our two Dutch case studies illustrate different complexities in multi-organisation coordination around heat network development.

Rotterdam

Rotterdam's harbour area is home to numerous resource intensive industries including oil refining and chemicals manufacture. Through the 1990s, harbour industries collaborated on a series of industrial ecology programmes, seeking to position environmental damage (including damage created by dumping residual industrial heat into the river) as a shared problem over which industry could influence solutions, rather than as a site of antagonism between industry, regulators, regional and state government, and environmental movements (Baas 2008; Baas and Korevaar 2010). Plant managers were willing to engage in coordinating activities, sharing data on plant performance to inform feasibility studies. Several different configurations of inter-industry heat transfer were examined, but plans to take heat from industry for use in space and water heating in domestic and public/commercial buildings in Rotterdam emerged as preferable, being perceived as creating less onerous interdependencies for the harbour industries. The district heating project, dubbed 'Warmtebedrijf' (heat company), thus emerged as a solution to a heat problem faced by the harbour industries.

Rotterdam's municipal government was not significantly involved in the industrial ecology programmes, having passed much of its environmental protection responsibilities to a regional body. However, around the same time as the early development of the Warmtebedrijf project, climate politics began gaining prominence in Rotterdam (for example, the Mayor signed up to the C40 Cities climate leadership group in 2007). The municipality thus sought a greater role in the heat project as a means of reducing the city's greenhouse gas emissions. The consequences of this involvement are contested. Some claim that trust between industrial ecology programme participants was undermined, that there were political mistakes and that new market procurement procedures, requiring competitive tendering and contractualisation, slowed development (Visser 2008). However, the municipality played a crucial role in constructing a heat market and stabilising the project as challenges emerged.

The original plan for the system was outlined in a 2005 business case (Warmtebedrijf Project Development Team 2005), jointly developed by the municipality, the port authority, the regional government, a housing corporation, three energy companies (who would distribute and retail the heat), and two companies from the harbour (who would supply the heat). The original plan was to take residual heat from an oil refinery and a waste incinerator and transport it via an 18 km pipeline into the central districts of Rotterdam as well as Hoogvliet, a regeneration area. The plan projected expansion of demand, the bulk of which would be connected over a decade, reaching heat delivery equivalent to the demand of 50,000 homes. Users would be a mixture of households (the largest single proportion), hospitals (playing key anchor roles), offices and various public and commercial buildings. Planned connections were a mixture of retrofit and new buildings, with about 80 per cent of the domestic load being new buildings.

The Warmtebedrijf company was established as a joint venture between the municipality (holding a 43 per cent share), the port authority (43 per cent), the Province of South Holland (10 per cent) and Woonbron, a housing corporation (6 per cent). It planned to construct and operate the heat transmission system to deliver heat into the areas identified for district heating. However, distribution and retailing of heat was established as a separate activity. The municipality divided up the district heating areas into a number of concession zones for competitive tendering. Two of the three energy companies involved in the initial feasibility study were awarded contracts.

The municipal authority used its building control powers to support the concession holders in developing the user base. In the areas targeted for district heating it adopted policies which were difficult to comply with using gas-fired boilers, but relatively easy through connection to district heating. The standard focused on comparative CO_2 emissions, whereas national regulation focused only on safety when comparing heating options. For retrofit connections the strategy focused on housing corporations. Connection to the heat network would improve the buildings' energy ratings, for which the corporations would then be able to charge higher rents. Both the new-build and retrofit market building strategies were bolstered by commitments to keep the costs of heating 20 per cent below gas-equivalents which had been written into the distribution/retail concession contracts.

Locking in heat supply proved more difficult, however. The project had grown out of voluntary cooperation among the harbour industries and was based on pre-empting environmental regulation of heat. The oil refinery was a source of risk to the initiative from the outset. The original business model relied on 25 years of operation, but the refinery owner (Shell) was willing only to sign a 15 year contract for the supply of waste heat. Shell would not charge for the heat, but insisted that heat supply must not interfere with its refining activities. The 2005 business case estimated the cost of connecting the refinery as €50m (with a 30 per cent margin of error). Through the period to 2007 this estimate increased, amid contested accounts as to whether political or technical factors were responsible. The cost of ensuring that the refinery would be able to eject heat, whether or not the heat network could take it, was the presenting reason for cost rises. Eventually Shell and the other project partners agreed to abandon connection of the refinery in 2007.

The withdrawal of the refinery threw the viability of the project into doubt. The Warmtebedrijf company requested bridging loans from the municipality, provoking division among local politicians as to whether sunk costs could be recovered by further investment or whether the company was effectively bankrupt and investment should be written off. The municipality suspended the initiative while the international financial accounting and business services consultancy KPMG was commissioned to develop an alternative business model. The third energy company involved in preparing the initial business case, E.ON, played a crucial role in the new approach. E.ON would take heat from the system for its existing heat network, and participate in commercial operation of the heat transmission system. However, it was not willing to accept infrastructure risks. The Warmteberijf was thus split into two companies, a public sector company responsible for developing and maintaining the heat transmission infrastructure, and a joint venture between E.ON and the municipality responsible for the purchase and sale of energy across the system.

Further problems on the heat supply side emerged in 2009. Following withdrawal of the refinery the planned system was dependent on heat from a waste incinerator located close to the district heating areas. Recession led to a fall in waste materials in the Netherlands leaving overcapacity in the waste management sector, and prompting withdrawal of the original incinerator. However, the municipal contract under which the waste company collected and processed Rotterdam's municipal waste required it to make heat available. The company now proposed to do this from a second incinerator located considerably further from the heat distribution zones, increasing the length of the transmission system from 18 km to 26 km. The financial strength of the municipality was crucial; its equity investment increased from €9m to €38m, and its underwriting of commercial loans increased from €58m to €150m (Warmtebedrijf 2010). The municipality claims that the increased costs will ultimately be borne by the waste company rather than users or public finances, as the tariff at which the energy trading Warmtebedrijf company purchases energy from the incinerator has been reduced.

The origins of the Warmtebedrijf project are similar to Bergen's heat network, in that environmental regulation meant organisations with large volumes of surplus heat were confronted with the problem of ensuring that heat was made use of. That is, the problem wasn't identified with a specific user (for example, a university seeking to reduce its energy costs), meaning the solution was agnostic to who the users were, as long as they could reliably be drawn onto the system. However, organising a solution to this problem was more complex than in Bergen, in part because of the voluntary participation of the harbour industries, reflecting their exploration of waste heat as an *option* to pre-empt specific regulation, and in part because of the improvised character of system planning and development in the absence of institutionalised mechanisms specific to heat networks. The capacities of the municipal authority were important to the project's survival through a series of set-backs. These include particularly its powers to build a user base through regulation of new and renovated buildings, to ensure through contractual provisions that heat from waste incineration would be available to the system, and to finance the escalating capital costs of the scheme. However, the control the municipality has been able to exert over the various elements of the initiative, particularly the supply of heat, is arguably weaker than the Swedish version of a municipally led model, where extensive municipal ownership coupled with a development model that integrated across different services was central to effecting coordination. This contrast is exemplified by the 'unbundled' model pursued for the Warmtebedrijf initiative: the initial model which separated heat generation, transmission and distribution/retail was further complicated by E.ON's requirement that construction and management of the transmission infrastructure be unbundled from energy trading across it. In Rotterdam while an unbundled approach has underpinned a series of coordination challenges, it has also afforded important flexibility to respond to changing circumstances.

In spite of the tumultuous early development, the project is now progressing. The two Warmtebedrijf companies were formally established in 2010. The main transmission pipe began delivering heat to the hospital in the winter of 2012/13. The system supplies heat to E.ON's existing heat network, and the new distribution networks in the concession areas are under development. The multi-organisation character of the scheme means the permutations of different organisational interests are complex and create additional management challenges. To take one example, E.ON sits on both sides of the transactions between the energy trading Warmtebedrijf company (in which E.ON holds a 50 per cent stake) and E.ON's heat distribution network. The arrangements are calculated to avoid a conflict of interest, but nonetheless a series of penalty clauses is embedded in the arrangement to prevent perceived abuse of E.ON's position. That is, while the flexibility for mixed public-sector and commercial activity within liberalised energy markets has supported development in Rotterdam, it creates new challenges in aligning different organisational interest. The next Dutch case study explores different challenges in aligning different organisational interests with more mature heat networks, and ways these can shape the development of physical heat network infrastructure.

Amsterdam

District heating is a central plank in Amsterdam's municipal sustainability programme, which targets a 50 per cent reduction in the city's greenhouse gas emissions between 2010 and 2025, and 'climate neutrality' for its own buildings by 2015 (City of Amsterdam 2010). The three principal means by which the municipality seeks to achieve these are: improving the thermal efficiency of buildings; supporting local renewable electricity generation; and expansion of district heating from the equivalent of 60,000 homes to 100,000 by 2025, and then to 200,000 by 2040. Expanding district heating presents two interacting coordination problems for the municipality: drawing users on to the expanding network, and negotiating development strategy with Nuon, a commercial energy subsidiary of the international utility Vattenfall.

There are two district heating networks in Amsterdam. The oldest (begun in 1997) and largest (47,000 household equivalents) is owned and operated by Nuon, takes heat from a large gas-fired CHP station and is located in the east of the city. The newer (2000) smaller (17,000 household equivalent) network in the west is a 50/50 joint venture between the municipality and Nuon, and draws heat from the city's waste incinerator, itself operated by a municipal company.

The municipality and Nuon describe a shared vision of an integrated district heating system, with the two networks eventually physically interconnecting to improve system efficiency. At present, however, the organisational form under which an integrated system would operate has not been decided. Options range from expanding the joint venture model to the whole system, through to full municipal ownership of network and heat generation. Key issues influencing decisions are the degree of control the municipality could exert (given that public policy goals may conflict with commercial priorities for the network), and Nuon's commercial interest and sunk investment (given that a change in ownership structure may dilute their stake in the business).

Public sector stakeholders in Amsterdam suggest that the capacity of the municipality to handle the commercial aspects of its involvement in district heating, and to analyse and shape the business in the city, is weaker than Nuon's. The municipality has limited access to data and expertise on the long-run development of the Dutch energy market (for example, the crucial issue of gas price trends), whereas Nuon can draw on Vattenfall's international resources and hedging strategies. While the 50/50 joint venture model for the west of the city network is identified by some as a strength, allowing public policy goals to be pursued in a commercially efficient way, some stakeholders express concern that the information asymmetry between Nuon and the municipality weakens the latter in negotiations. Particular areas of negotiation where these asymmetries may be relevant focus on issues where the municipality's social and environmental objectives may not align with Nuon's commercial interests. These crucially include appraisal of the investment case for network extensions, and analysis of different options for integrating the two networks.

One specific example illustrates the challenge of governing district heating in this context. The geography of Amsterdam, with canals and a river separating areas of dry land accentuates certain challenges. The prevalence of canals in the historic centre means that the area is not considered suitable for district heating. However, existing networks do cross bodies of water between islands and across the river. Zeeburger island, to the east of the city, is strategically located as a potential link across the river, extending Nuon's network from the east towards the north of the city where the joint venture network is already developing. Furthermore, proposals for the Zeeburger island network identify the joint venture business as the developer and operator of the network, making it the first instance of (organisational) integration across the systems.

Connection of Zeeburger exemplifies the tensions between Nuon's commercial interests and the municipality's ambition for an integrated heat network. Zeeburger would be a crucial bridge between the two systems, making it strategically valuable. However, in the absence of an agreed business structure for a future integrated system, Nuon argues this cannot be factored into its commercial model. Instead, the company focuses on heat sales on the island, and argues that connection of all new development proposed would be needed for heat sales to satisfy its hurdle rate of return. The municipality, through its building and planning control powers, has the capacity to force all new buildings on the island to connect, but some officers have expressed concern about their perceived informational disadvantage in negotiations with Nuon, and note that developers reacted negatively to the proposed loss of discretion they are given in other zones targeted for district heating in the city.

In Amsterdam, as in Rotterdam, municipal capacity to shape heat supply decisions, particularly for new buildings, is crucial to mitigating uncertainties in the scale of a network's future user base, and thus to supporting investment in an expanding network. Without a municipal energy company, Amsterdam's municipality has depended on commercial engagement with Nuon to develop district heating. While this has been regarded as contributing to successful expansion of the joint-venture heat network based on waste incineration, the multiplicity of interests and their uncertain role in a future system creates challenges in construction of a single city-wide network, which would have greater efficiency and flexibility than two separate systems. The challenge stems not simply from differences between commercial and social/environmental objectives, but from the prospect of changes to each party's ownership and control over energy generation and infrastructure assets. The connection of Zeeburger island is thus positioned ambiguously: from one perspective its value lies in its contribution to establishing an technically integrated system, but from another that value cannot be clearly identified given uncertainties in ownership and control over the envisaged future system.

Conclusions

High capital costs and long development time scales mean establishment and expansion of large heat networks in Europe has depended on capacity of a system-building agent to organise and hold stable a group of users whose long-term heat demand can justify near-term investment. The development of district heating in Denmark and Sweden depended on municipal authorities to effect this coordination, relying on newly instituted heat planning processes in Denmark, and existing municipal integrated service planning in Sweden. Not only did municipalities possess the capacity to develop heat networks, district heating was positioned as a solution to the harms local populations and businesses had suffered through exposure to fluctuating oil prices, problems which municipalities assumed responsibility for mitigating. In both countries, with local capacities and objectives aligned around district heating, national governments were able to use taxes and subsidies to support heat network development and to influence decisions within district heating enterprises, particularly in relation to choice of fuels.

Liberalisation of energy markets and the broader shift away from local government direct provision of services change the capacities of local authorities to coordinate the development of new heat network infrastructure. This does not mean heat network development is no longer possible, but the organisational challenges of locking different components of a system in place have been accentuated. Development has become dependent on a greater variety of relationships than in the historical case of municipal ownership. For example, the initial impetus for district heating in two of the contemporary cases discussed here came from organisations who lacked capacities to develop heat networks: in both Rotterdam and Bergen regulation framed surplus heat as a problem for organisations whose core activities were far removed from district heating, necessitating multi-organisation collaboration.

Norwegian area-based district heating licencing creates a framework for heat network planning, particularly the protection of an identified user base, which can be used by various organisations, not just local authorities. While this was effective in Bergen, the case nonetheless illustrates that local government retains important capacity, in the form of spatial planning and building control, to help shape network development and coordination with users. In the Netherlands, where national regulation of district heating does not establish a framework for system planning, these capacities of local government are even more central.

What, then, do these cases imply for European states and the policies they could adopt in compliance with the EU Energy Efficiency Directive's requirement that '[account] shall be taken of the potential for developing local and regional heat markets'? While financial incentives such as grants, taxes and subsidies can steer the development of heat markets these alone are unlikely to be effective. Large scale heat infrastructure development depends on agents with sufficient capacity to coordinate such development, and on agents for whom large scale heat network development is a central objective. Whereas in Danish and Swedish heat network development these capacities and objectives tended to be concentrated in municipal authorities, contemporary forms of heat network development appear more organisationally heterogeneous. The scope for multi-organisation collaboration will thus be an important factor shaping the development of heat networks, and the form such collaboration takes is likely to reflect broader traditions of economic coordination within different countries (Hawkey and Webb 2014).

The following chapters of this book examine in greater depth various aspects of local energy development, focusing particularly on the UK where large scale heat network development is currently uncommon. In particular, chapters 4 and

5 explore the development of national policies and their interaction with local practices while chapters 6 and 7 discuss in detail the wide variety of models of and approaches to local coordination around new heat infrastructure.

Note

1 The peer exchange visit took place in 2012 and was part of CASCADE, an international knowledge development project funded by Intelligent Energy Europe. It included a mixture of practitioner and expert representatives from England, Germany, Italy, Scotland (including this chapter's lead author) and Spain. See www.cascadecities.eu.

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4

FROM OPTIMISATION TO DIVERSITY

Changing scenarios of heating for buildings in the UK

Mark Winskel

Introduction

This chapter reviews a number of recent UK energy system scenarios with a particular focus on heating for buildings (space and water) heating.[1] The review is necessarily selective: reflecting the UK's relatively fragmented systems for energy research and policymaking (Winskel and Radcliffe 2014), there are now many different scenarios of UK energy and heating futures, commissioned and undertaken by, variously, government departments and their official advisors, industry associations, policy think tanks, consultancy firms and university-based research groups.[2]

The use of scenarios is often associated with an effort to develop a 'whole system' view of the social and technical interactions and uncertainties involved in complex infrastructures such as the energy system (e.g. Skea *et al*. 2011b; IEA 2014); as the UK Government argues, the envisaged UK transition to low carbon heating invites an understanding of the wider whole energy system context:

> The heat challenge is a 'systems problem' and can be addressed at different levels … it cannot be fully solved by considering one part of the solution in isolation … the heat question is also the electricity question, the storage question and the infrastructure question.
>
> *(DECC 2013: 8)*

As well as the substantive focus here on low carbon heating, an underlying concern is the challenge (and value) of long-term holistic framings of complex socio-technical change; this includes a number of interrelated issues or meta-themes related to scenario processes and methods: the role of quantitative modelling in scenario exercises, the organisational settings for research-policy exchange, and the challenge of whole systems research and policymaking in post-technocratic institutional and governance contexts.

Following a short reflection in the rest of this section on the chequered history of energy scenarios, the next section focuses on 'official' or mainstream versions of the future – especially those articulated by the UK Government and its statutory advisors, the Committee on Climate Change (CCC). This is followed by a section which reviews a few prominent alternative, marginal or 'unofficial' scenarios commissioned by groups such as industry associations and independent think tanks, and carried out by consultancy firms and academic researchers. (In practice, there is no hard division here: as this chapter explores, UK official policy reviews are typically informed by directly commissioned or independent consultancy studies.) The final section summarises the findings and considers the wider meta-themes listed above.

Beware … scenarios ahead!

> Reflecting on how the world has changed in the past provides a healthy reminder of how much can change … going back 40 years takes us to a world where the oil crises had never happened … and global warming was the forgotten theory of 19th century physicists.
>
> *(Skea et al. 2011a)*

Scenarios have a long and chequered history in the energy sector, and the expectations of energy futurologists have often been confounded (Hughes and Strachan 2010; McDowall *et al.* 2014). Rather than any predictable working-out of consistent long-term objectives and trends, the broad pattern of energy system change has been one of gradual evolution interspersed with periods of crisis and more disruptive change – an unpredictable pattern of change sometimes referred to as 'punctuated equilibrium' (Levinthal 1998).

In the UK, for example, energy system development can be divided into distinctive periods, from early fragmented local systems in the late-nineteenth and early twentieth centuries, partial centralisation and consolidation in the inter-war years, post-war nationalisation and corporatism, and privatisation and liberalisation at the end of the twentieth century (Hannah 1979; Helm 2003). The transitions between different periods were typically disruptive, politically contested and driven by events such as geopolitical crisis or war which were largely beyond the control of energy policymakers and industry managers (Hughes 1983). The direction and pace of change were often unanticipated: for example, few observers predicted that the major change in electricity generation following privatisation in the early-1990s would be a rapid and transformative 'dash-for-gas' (Winskel 2002).

It is tempting to use the benefit of hindsight to highlight the unrealised visions of energy experts and managers from the past. In 1970 Sir Stanley Brown, the then Chairman of the Central Electricity Generating Board (CEGB) confidently predicted the continuing expansion of the UK electricity supply industry, so that by

1995 it would have grown three-fold, with nuclear power by then well-established as the dominant supply technology, and fossil fuels reduced to a marginal role (Brown 1970). In reality, the UK energy industries in 1970 stood on the cusp of two decades of disruptive change, culminating in the overthrow of the seeming impregnable authority of the CEGB itself (and its preferred technologies); as Leslie Hannah stated, 'all [the] assumptions, built up over more than six decades of experience, proved false' (Hannah 1982: 288).

In the decade or so after the privatisation of the UK energy industries at the end of the 1980s there was a turn away from scenario making, whole systems thinking and long-term planning, with an emphasis instead on short-term market-based decision-making (Winskel 2002). The start of the new millennium saw the rise of new long-term concerns, especially climate change (RCEP 2000), eventually manifesting in the UK Climate Change Act (CC Act) (UK Government 2008). The CC Act translated an established government ambition for long-term decarbonisation of the UK economy into a statutory commitment, with step-by-step emission reductions to be achieved through ever-tightening 'carbon budgets' between 2009 and 2050. The Act therefore heralded a return to long-term energy system steerage, with an attendant resurgence of energy futurology and scenario making (Zeyringer 2014).

The evident historic shortcomings of energy scenarios raise a question-mark over their value and legitimacy in contemporary policymaking and research. The justifications offered here include the need to strive for economic efficiency and public accountability in navigating change under uncertainty – for example, the UK Government has argued that scenarios 'illustrate some of the ways in which it is possible to allocate effort … show some different perspectives on how the [policy] target could be met' (UK Government 2010: 15).

Without the historians' privilege of hindsight, contemporary policymakers and strategists are confronted by a familiar challenge: the need to steer a long-term transition in the face of multiple imperatives and uncertainties. Just like their predecessors, contemporary energy planners are likely to have their unrealised expectations highlighted by future generations of historically minded researchers.

Nevertheless, this chapter concludes that rather than abandoning whole systems scenarios in the face of unpredictable social, economic and technological developments, changing policy priorities and institutional fragmentation, the need is for improved ways of representing and deliberating long-term socio-technical change, as part of accountable governance and decision-making.

Mainstream energy futures

Introduction: policy context

The period since the passing of the CC Act in late-2008 has seen unprecedented attention on 'heat policy' within wider UK energy policy. The CC Act implies a near-wholesale shift away from the currently dominant form of heating buildings – unabated natural gas – by 2050 (Ekins *et al.* 2013; Eyre and Baruah 2014). The Act established a long-term decarbonisation target for the UK for an 80 per cent reduction in greenhouse gas emissions compared to a 1990 baseline, with the decarbonisation trajectory from 2009 to 2050 defined by a series of five-year carbon budgets (UK Government 2008). Statutory responsibilities for compliance with the Act lay with a newly formed branch of government, the *Department of Energy and Climate Change* (DECC) and a new statutory advisory body, the *Committee on Climate Change* (CCC). In this section we discuss the evolution of DECC's and the CCC's energy system scenarios, and within this, changing visions for how heat used in buildings might be decarbonised.

Alongside the CC Act, a number of other major policy developments have influenced the envisaged pace and direction of UK energy system change, especially the EU Renewables Directive and Emissions Trading Scheme (ETS). Under the Renewables Directive (CEC 2009), the UK Government agreed to a highly ambitious target of 15 per cent of all energy consumed to be produced by renewables by 2020. Because renewables were seen as more readily substitutable in electricity supply than heating and transport infrastructures, DECC's 'lead scenario' for complying with the Directive had 30 per cent of UK electricity from renewables by 2020, requiring an unprecedented deployment programme of renewable electricity, especially windpower (UK Government 2009c: 11). The more modest (though still challenging) targets for renewable heat and transport by 2020 were 12 per cent and 10 per cent, respectively.

The ETS also affected policy responses to the problem of low carbon heat for buildings. It set a EU-wide limit up to 2020 on certain 'traded sector' carbon emissions, such as those from the power sector and energy-intensive industry. Because UK national carbon accounts adopt ETS-defined levels for the traded sector emissions, domestic policy cannot change this part of the carbon budget. UK policy can, however, affect 'non-traded' emissions. The result has been to place relative UK policy emphasis on emissions from non-traded parts of the economy (such as heating for buildings) in domestic responses to UK decarbonisation policy to 2020; according to one DECC senior policy official, 'the strong story is "you're not going to make your carbon budgets unless you do something about heat" ' (pers. interview 2013).

UK Government scenarios

The first major high-level analysis of energy futures published after the CC Act was the Government's *Low Carbon Transition Plan* (LCT Plan) (UK Government 2009a). The Plan addressed economy-wide challenges in meeting the first three UK carbon budgets between 2009 and 2022. For the energy sector, economic optimisation analysis by DECC using the 'MARKAL' energy system model[3] suggested that much of the scope for change over this relatively short time period lay with improved energy efficiency and the rapid expansion of large scale renewable electricity supply (UK Government 2009b). (Alongside the LCT Plan, DECC was also formulating a

Renewable Energy Strategy, consolidating the imperative for renewable *electricity* expansion implied in the *Renewable Energy Directive* (CEC 2009; UK Government 2009c.))

Although it was published several months after the height of the international financial crisis, the LCT Plan struck a confident tone on the capacity of UK energy policymakers and strategists to respond to the decarbonisation challenge. It also showed evidence of whole systems thinking, at least at the *macro-level* of the national energy system, and the *micro-level* of individual households – with repeated references, for example, to alternative uses for biomass resources across electricity, heating and transport, and to the need for 'whole house' approaches to energy efficiency. However, much *less* attention was paid to the intermediate *meso-level*, with only passing reference to community-level energy. Even so, the LCT Plan suggested that local authority-led community/district heating schemes could be a growing share of UK domestic heating, up to 14 per cent; it also included financial support for 'exemplar' district heating schemes across the UK.

The LCT Plan focused on providing a 'route-map' for the UK energy transition to 2020, with post-2020 change understood essentially as a follow-on problem. In 2010 the newly formed Conservative/Liberal Democrat coalition government issued a study of longer-term energy futures, the *2050 Pathways Analysis* (UK Government 2010). Rather than economic optimisation modelling, this was based on 'physical and engineering' modelling by DECC using a web-based tool known as the *Pathways Calculator*. The Pathways Analysis involved constructing alternative ways of achieving the CC Act's '80% by 2050' target, differentiated mainly by their relative emphasis on a handful of large scale low carbon electricity supply technologies: fossil fuels with carbon capture and storage (CCS), renewables (especially large scale windpower and bioenergy) and nuclear power – as well as energy demand reduction through behaviour change.

Overall, the Pathways Analysis suggested a two-phase approach to UK energy system change, with an early emphasis (up to around 2030) on demand reduction and electricity supply decarbonisation, followed by a massive expansion of (by then carbon-free) electricity supply after 2030, to enable the electrification of heating (using building scale electric heat pumps) and transport (using electric vehicles). Low carbon heating was envisaged as undergoing a major transition after 2030, with the likely marginalisation of the UK national gas grid by 2050 – though with recognised uncertainties on heat pump adoption rates, given the lack of UK experience.

In the short period between the passing of the CC Act in late-2008 and the end of the decade, the 'all-electric' energy system became an established vision for the UK's energy future among mainstream whole system policy and research communities (CCC 2008; UKERC 2009). For domestic heating, this was prominently advocated by DECC's then Chief Scientific Advisor, Professor David MacKay; in an influential book, MacKay asserted that the UK 'should leapfrog over gas powered combined heat and power and go directly for heat pumps … we should replace all our fossil-fuel heaters with electric powered heat pumps' (MacKay 2009: 153).

A more detailed longer-term official analysis emerged in late-2011, in the form of the *Carbon Plan* (UK Government 2011). The Plan identified UK government-wide

TABLE 4.1 Carbon Plan scenarios

	'Core Scenario'	*'Renewables & Efficiency Scenario'*	*'Nuclear Power Scenario'*	*'CCS & Bioenergy Scenario'*
Energy saving per capita by 2050, %	50	54	31	43
Electricity demand increase by 2050, %	38	39	60	29
House-level buildings heating in 2050, %	92	100	90	50
Network-level buildings heating in 2050, %	8	0	10	50

Source: UK Government (2011, based on Table 1, p. 19).

responsibilities for managing the transition to a low carbon economy, with detailed actions, timelines and decision points for all major departments; it quickly became a key reference document for policymakers and researchers. The Carbon Plan's scenarios were developed using more sophisticated techno-economic systems modelling than used in the Pathways Analysis. Three energy system models were used: 'MARKAL', the 'ESME' techno-economic optimisation model developed by the Energy Technologies Institute, and the DECC Pathways Calculator (UK Government 2011). Like the Pathways Analysis, however, it differentiated between a handful of pathways in terms of their relative emphasis on energy efficiency and a few large scale electricity supply technologies.

The Carbon Plan understood the UK's domestic heat transition as a gradual process taking many decades to complete, with a continuing central role for incumbent technology (building-level gas-fired condensing boilers) for much of the transition. The mass deployment of low carbon heating technology was not expected to get under way until a decade or more of trialling and demonstrating emerging alternative technologies. Thereafter, in the 2020s, the Plan envisaged a playing-out of market competition between *house-level* (or building-level) technologies (especially electric heat pumps) and *network-based* technologies (especially district heating). Detailed modelling of buildings (using a model developed by consultants NERA and AEA for the Committee on Climate Change) suggested that for most buildings, house-level technologies were likely to offer more affordable low carbon heating than network-level technologies, and the former dominated future heating in three of the Carbon Plan's four whole energy system scenarios (Table 4.1).

In its overall assessment of the future of heating for buildings, however, the Government suggested a balanced emphasis on house- and network-level technologies, with heat networks possibly viable for meeting around half of UK buildings' heat demand. As such, network-level technologies were seen as a flexible alternative to building-level technologies. The Government also recognised that low carbon

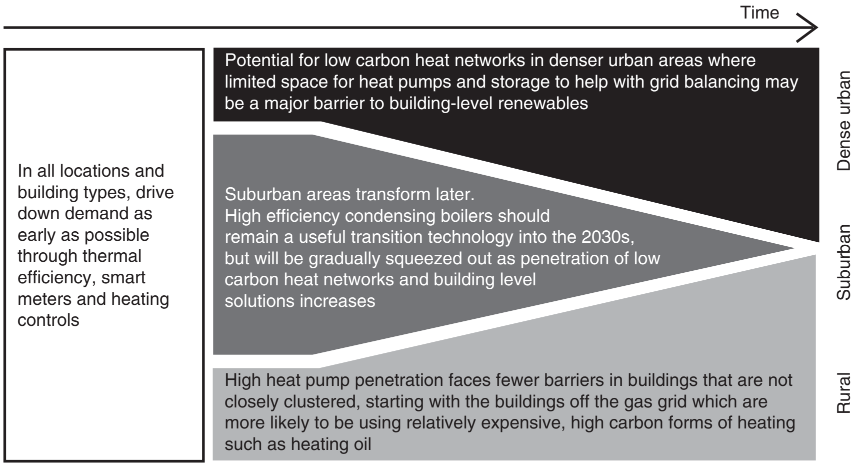

FIGURE 4.1 A strategic vision for UK buildings heating. Source: DECC (2012: 97).

heating was an area of particular uncertainty, and announced that it was to undertake development of a fuller heat strategy.

That strategy was first published in early 2012, as the Government's *Future of Heating* strategic framework (DECC 2012). The framework drew on expert evidence from a number of organisations: the CCC, Energy Technologies Institute (ETI), industry workshops, field trial evidence, and also, a number of different models – both whole energy systems (MARKAL, ETI's ESME model and DECC's Pathways Calculator) as well as more detailed sector-specific models developed by consultancy firms NERA/AEA and Redpoint. The Government identified a number of common messages from the different studies: for individual buildings these included the complete phasing-out of natural gas boilers by 2050, with a reliance on heat pumps for much low carbon heating. However, the Government also noted that all models struggled to represent and compare network technologies with building-level technologies, so that a 'broader evidence base' was needed to make this comparison (ibid., p. 9).

A heat map of England, published alongside the strategic framework, was seen as suggesting that heat networks could supply up to half of all heat demand. While recognising the uncertainties associated with heat network development (such as the risk of asset stranding if affordable low carbon fuel supplies were to prove limited) the Government concluded that heat networks had an increasing role to play in the UK energy system, given the challenges of mass deployment of building-level heat pumps in dense urban areas. Like the Carbon Plan, the *Future of Heating* saw the next decade as essentially preparatory, ahead of mass deployment of low carbon technologies in the 2020s and 2030s; for heat networks, this preparatory phase involved cost reduction efforts and the building-up of local supply chains. Although modelling still suggested a dominant role for heat pumps by 2050, the overall strategic vision involved a dual emphasis on network-based and household-level technologies (Figure 4.1).

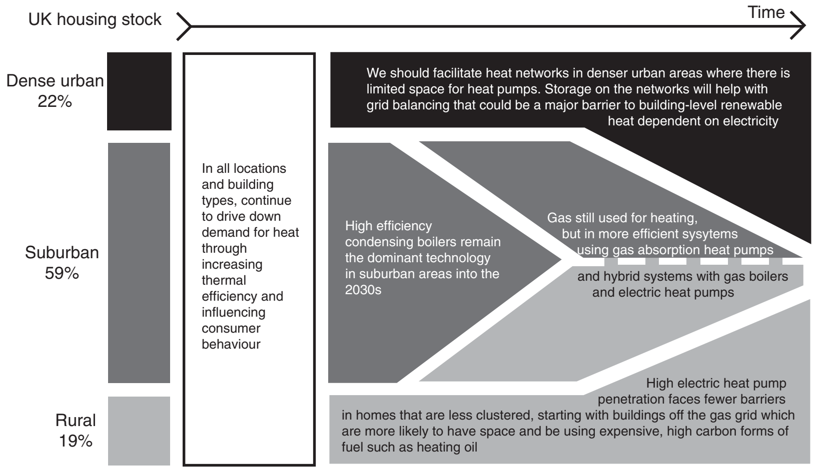

FIGURE 4.2 Updated strategic vision for UK buildings heating. Source: DECC (2013: 78).

Further analyses were presented a year later, in early 2013, in a second major official heat strategy statement (DECC 2013). The new studies involved the use of two different energy system models (ETI's ESME model and consultancy firm Redpoint's RESOM model); the revised strategy was also informed by greater reference to existing consultancy studies (Pöyry Energy and Faber Maunsell 2009; Delta 2012). The new modelling incorporated more detailed representation of UK heat demand fluctuations, revised technology costings and the inclusion of several previously unrepresented technology types.

Although the Government asserted that the new modelling had 'confirmed and increased confidence' in the heat decarbonisation pathway set out in the Carbon Plan, it noted that 'a more detailed understanding' had now emerged (DECC 2013: 14). In particular, the results suggested that the UK's heating transition could involve a much more diversified range of heat technologies than previously thought. While there were some inconsistencies between the results of different models, broad areas of agreement included a mass roll-out of heat pumps, a greater than previously suggested probable role for heat networks, and an important transitional role (between 2020 and 2040) for 'hybrid' heat pump technologies (using gas as well as electricity) not previously represented in model specification. Contrary to the Carbon Plan scenarios, the new modelling also suggested a continuing role for natural gas networks in 2050 for meeting peak heating demand.

The revised vision was encapsulated in an updated transition diagram, significantly changed from its equivalent from a year earlier (Figure 4.2). The Government announced that continuing uncertainties meant that further modelling and field trials were needed across a range of household-level and network-level technologies. However, while DECC's revised heat strategy challenged some aspects of the Carbon

Plan, the Government reiterated its overall policy vision for technology-neutrality and governance by market-based selection among competing options: '*Across all the different heating strands, the Government wants to make progress without prescribing the use of specific technologies. Instead, information for market players, including households and businesses, should be improved to enable effective decision-making*' (DECC 2013: 79).

UK Committee on Climate Change

The Committee on Climate Change has a key statutory role in UK energy policy, advising national and devolved governments on emissions targets, and offering reports to parliaments on decarbonisation progress. In late 2008, just after the passing of the CC Act, the Committee published *Building a Low Carbon Economy*, a detailed analysis of economy-wide pathways for the first three five-year carbon budgets, covering the period 2009–23 (CCC 2008). The CCC's analysis of the future of the UK energy system drew heavily on the same MARKAL model as the Government used in the LCT Plan. In justifying its use, the CCC suggested that the model set out an 'ideal' recipe for energy system change and policy support:

> The MARKAL model … provides an indication of what could be achieved under optimal policy and decision-making; by definition, deviation from this optimal solution will tend to increase overall costs … we have not used the model to specify a precise path, but to establish that such a path can exist and how much it would cost.
>
> *(CCC 2008: 77)*

The CCC's analysis identified an optimal pathway for UK energy system change to the early 2020s based on a dramatic expansion of renewable electricity generation and much greater efforts on energy efficiency. As with the *Low Carbon Transition Plan*, *Building a Low Carbon Economy* was developed at a time when DECC was anticipating the massive expansion of renewable electricity to 2020 to comply with the Renewable Energy Directive. Over this relatively short timescale, domestic low carbon heating was seen by the CCC as requiring the rapid deployment of relatively mature renewable heating technologies, especially biomass boilers for off-grid properties and solar thermal water heating (ibid., p. 236). By contrast, the prospects for significant deployment of heat pumps and district heating over this period were seen as very limited.

Two years later, in late 2010, the CCC published its initial advice on meeting the fourth carbon budget, covering the years 2023–27, with much of the analysis running to 2030 (CCC 2010). The Committee's new scenarios and supporting research now questioned the role of domestic biomass boilers in the UK, reflecting concerns about the availability of sustainable biomass resources and the impacts of biomass boilers on urban air quality (CCC 2010: 212). The UK's limited biomass resources, the Committee concluded, were likely to be better used in the industrial sector, where there were few other low carbon options.

Instead of biomass, the CCC's fourth carbon budget scenarios emphasised the role of heat pumps. In its 'medium abatement' scenario, for example, building-scale heat pumps supplied three-quarters of low carbon heating and almost one-quarter of all heating for buildings by 2030 – a remarkable expansion from a near-zero starting point; other low carbon technologies, such as biomass, biogas and district heating made only minor contributions. While district heating was seen as 'a promising option' (ibid., p. 217), Committee concerns about the availability of carbon-free fuel sources for heat networks, and other uncertainties, led it to assume relatively low deployment levels by 2030. At the same time, the Committee recognised that the 'economic deployment' of heat networks may be higher, and called for further work to determine its optimal role in contributing to carbon budgets.

To inform its advice on the transition to low carbon heating for buildings up to 2030, the CCC commissioned a detailed consultancy study (NERA and AEA 2010). Under central assumptions, the modelling suggested that a heat pump electrification strategy was the preferred alternative for decarbonising most UK buildings, provided that improved heat pump technology was developed over the next two decades. In an alternative scenario, however, under changed assumptions, both bioenergy and district heating also played significant roles. District heating was seen as potentially 'a very attractive abatement option', provided that affordable low carbon heat sources were available and adoption barriers were overcome.

In April 2012 the CCC published an updated assessment of low carbon heating (CCC 2012), informed by scenarios to 2050 devised by consultancy firms Element Energy and AEA (Element Energy and AEA 2012a) – the first time the CCC had published a detailed analysis of long-term heating futures. Given the greater uncertainties involved over this longer time frame, the study did not attempt to identify a central scenario. Instead, three different possible heating pathways were elaborated, differentiated according to their emphasis on building-level solutions (mainly heat pumps), network-level solutions (mainly district heating) and electrification (using direct electric heating). The approach was designed to 'help derive and understand the implications of a range of illustrative … futures' (Element Energy and AEA 2012b: 4).

Drawing on the Element Energy and AEA scenarios, the CCC concluded that in many locations, no clear cost advantage for heat pumps or district heating could be established (electrification using direct heating was considered more expensive than both). Rather, the optimal balance depended on location-specific considerations and 'the extent to which policy was developed to address the challenges of community scale heat supply' (CCC 2012: 65). The CCC concluded that the level of UK buildings' heat demand which might be affordably met by district heating by 2050 was extremely uncertain: between 2 per cent and 40 per cent (ibid., p. 77).

In late 2013 the CCC published revised fourth carbon budget advice to the UK Government, almost three years after its original advice (CCC 2013a). By now the full economic impact of the economic recession in the wake of the 2008 financial crisis had become clear, and UK long-term energy demand projections had been revised significantly downwards. Given this, the Committee now judged that the decarbonisation pathway consistent with CC Act carbon budgets could be achieved with more 'prudent' assumptions regarding the roll-out of low carbon technologies. On heating and energy efficiency technologies, this involved some much reduced expected contributions, and new consultancy analysis, field trial evidence and industry and stakeholder consultation highlighted a number of previously underappreciated technical, economic and consumer challenges associated with heat pump deployment in the UK (CCC 2013b; Frontier Economics and Element Energy 2013).

The Committee judged that although many of these concerns could be addressed over the longer term, they implied a much more cautious approach over the short term. By contrast, district heating was now seen more favourably, and the Committee offered a substantially revised central estimate of the make-up of the heat system in 2030, with expectations of heat pump deployment halved and district heating trebled. A balanced mix of heat pumps and district heating was thought likely to have similar costs and carbon emissions as a pathway dominated by heat pumps. Given the multiple uncertainties involved, the Committee concluded that policy support measures should be devised to actively 'keep open' the possibility of substantial contributions from both heat pumps and district heating by 2050.

Alternative futures and comparative analysis

Alongside the official versions of the future articulated by the UK Government and Committee on Climate Change, many other scenarios of future UK heating for buildings have been devised since the passing of the CC Act in 2008. Only a small illustrative sample of these alternative futures, and also some comparative studies of different scenarios, are reviewed here. While also designed to influence policy, these are less directly involved in mainstream policymaking, and are typically commissioned by industry associations, policy think tanks or civil society groups, and carried out by consultancy firms or academic research groups. As such, they may be oriented to particular technologies or policy problems rather than a whole systems analysis. They may also be explicitly designed to offer a counter-narrative to mainstream scenarios.

One such study was commissioned by the Combined Heat and Power Association (CHPA) to consider an expanded role for district heating in UK energy futures (Speirs *et al*. 2010). In doing so, this study offered a direct critique of the all-electric UK energy vision that emerged in mainstream scenario studies in the period immediately after the passing of the CC Act. Speirs *et al*. (2010) reviewed a number of existing energy scenarios by DECC, the CCC and UKERC; all were constructed using the MARKAL energy system model (see above), and all identified electricity-based heating using building-scale heat pumps as the likely dominant technology for future UK heating.

Speirs *et al*. (2010) identified a series of weaknesses with the modelling underpinning the all-electric vision: partial and inaccurate technology characterisation, a tendency to 'winner-takes-all' technology selection rather than a valuing of diversity, an under-appreciation of 'real-world' technical, engineering and manufacturing limits, and a misleading assumption of economically rational decision-making. The MARKAL model was also seen as having a number of other structural biases and oversights: a narrow pursuit of decarbonisation above wider resource efficiency, an orientation toward technology substitution in existing infrastructure rather than transformative shifts to distributed systems, an under-representation of more mature 'transitional' technologies, and an inability to reflect local contexts (Speirs *et al.* 2010).

To illustrate the implications of these weaknesses, and the feasibility of other futures, Speirs *et al.* (2010) constructed an alternative scenario, based on a CCC scenario and compliant with CC Act targets, but with changed assumptions for biomass, carbon capture and buildings insulation technologies. The alternative scenario was designed to make early cuts in carbon emissions through greater use of transitional technologies, which had higher value when seen from a cumulative emissions perspective (rather than a 2050 end-point perspective). The result was the greater use of district heating than in the CCC original scenario (supplying 14 per cent of UK buildings heat by 2050) powered mostly by large scale CHP. Overall, Speirs *et al.* concluded, a policy focus on *diversity* rather than *optimality* offered a more robust low carbon heat future for the UK.

Another study, commissioned by the Gas Futures Group of the Energy Networks Association, and carried out by the consultancy firm Delta EE, was designed to consider the UK domestic heating transition in terms of its implications for consumers, and for existing gas and electricity distribution networks (Delta 2012). The study involved developing detailed disaggregated models focusing variously on housing stock, heating technologies and customer uptake. Three alternative versions of the UK heat transition to 2050 were devised using these models: a 'customer choice' scenario which saw the continued use of natural gas boilers in many homes but which achieved only modest decarbonisation; an 'electrification and heat networks' scenario which achieved almost complete decarbonisation using heat pumps and district heating (resembling DECC's original heat strategy vision); and a 'balanced transition' scenario which achieved 90 per cent decarbonisation using a mix of heat pumps, resistive electric heating, heat networks and hybrid gas-electric heat pumps (resembling DECC's revised heat strategy vision).

Delta argued that their balanced transition pathway offered a relatively non-disruptive and affordable way of meeting policy targets, with greater technology variety, reduced infrastructure costs and lower demand than in the electrification and heat networks scenario. However, Delta noted the need for strong coordination mechanisms to realise a balanced transition, and called for different planning zones to be established for district heating-, gas- and electricity-based heating technologies, given the sensitivity of preferred solutions to housing type, and the need to avoid network duplication. Like Speirs *et al.* (2010) Delta concluded that 'keeping a variety of options open … gives lower risks and potentially a lower cost path' (ibid., p. 5).

By 2014 a number of comparative reviews of different heating scenarios had emerged. As well as benchmarking different studies against each other, these 'meta-studies' also offered an opportunity for some critical reflection on the role of scenarios and modelling in UK energy policy. In a study sponsored by the Institute of Gas Engineers and Managers and the Energy and Utilities Alliance, Carbon Connect (an independent policy forum) compared six prominent UK buildings' heating scenarios to 2050, from DECC, the CCC, ETI, National Grid, UKERC and Delta (Carbon Connect 2014). Carbon Connect's analysis involved systematically reviewing different scenario studies in terms of their varying input assumptions, modelling processes and scenario outcomes for key prospective solutions – and so highlighting areas of agreement and disagreement (Box 4.1).

Carbon Connect also made a number of critical observations on scenario development processes. System-wide national energy models, it noted, while seeking out the cheapest overall system design, were unable to simulate the behaviours of users and investors, the impact of particular policies, or the thermal characteristics of the UK building stock and network geography – all critical issues for assessing heat futures. On the other hand, more detailed buildings or network models, while allowing more granularity and better representations of some technologies, failed to model wider energy system interactions (see also Dodds 2014).[4]

Carbon Connect called for the development of a stronger evidence base for heating scenarios, with better representation of local areas, consumer preferences and supply chain capacities. It also called for improved scenario processes, with independent access to energy network data, greater transparency of scenario methods and more careful communication of results. It concluded that scenarios were complex pieces of work that required careful interpretation: 'there is a risk that their results are misunderstood because there is not enough context to understand their assumptions and limitations' (Carbon Connect 2014: 7).

Another comparative review of several UK heating scenarios highlighted the sensitivity of scenario outcomes with model choice and input assumptions (Chaudry *et al.* 2014). It also noted an emerging gap between the implications of many long-term heating scenarios and actual policy and energy system developments: for example, without major policy changes, it noted, heat pump deployment by 2030 would remain well below the level identified by the CCC as being necessary to keep open the possibility of a major role for the technology in 2050. Chaudry *et al.* concluded that the wide variation in scenario results and the multiple long-term uncertainties involved implied a need for 'balanced support' for network- and house-level technology trials and learning over the next decade.

In another critical reflection on official scenarios of UK domestic heating Eyre and Baruah (2014) suggested that both DECC's revised heat strategy and the CCC's revised fourth carbon budget advice had an undue orientation to supply technologies above buildings' efficiency and refurbishment. Not only was this inconsistent with the Government's declared policy priorities, they argued, it also meant that supply technology scenarios may be based on implausibly high future demand. Both DECC and

BOX 4.1 MAJOR VARIABLES IN UK BUILDINGS HEATING SCENARIOS (based on Carbon Connect 2014)

Energy efficiency: the estimated energy savings from efficiency measures vary considerably across different scenarios, from 5 per cent to 30 per cent. There is an important interaction between energy efficiency and preferred low carbon heating systems, as the demand-reducing benefits of efficiency are less valuable for high fixed cost technologies, such as heat networks.

Natural gas: although the contribution from gas falls greatly (by at least 75 per cent) in all scenarios compliant with the CC Act, scenarios differ on its continuing role in 2050, given uncertainties over the cost of decarbonisation in other sectors, such as transport and industry, and the most economic ways to meet seasonal peak heating demand.

Electricity: electricity provides between 30 per cent and 75 per cent of buildings heating in 2050, predominantly through heat pumps. This varies with assumptions such as the thermal efficiency of buildings, heat pump compatibility with existing radiator technologies and the carbon intensity and costs of low carbon grid electricity. Other electricity-based technologies, such as resistive storage heaters, are poorly represented in some scenarios.

District heating: the biggest missing piece of the heating 'jigsaw puzzle', due to the difficulty modelling its economic sensitivity to local geography. Where available at competitive cost, it could supply up to 40 per cent of UK buildings heat in 2050, and provide wider energy system and consumer benefits, but these are also poorly captured in scenario analysis. However, district heating faces a number of uncertainties, including the affordability of low carbon heat sources.

CCC scenarios were also criticised for partial technology representations and unrealistically high anticipated deployment rates for heat pumps and hybrid heat pumps. At the same time, recent scenarios with high heat network contributions were predicated on another major uncertainty: the recovery of heat from future large scale power plants.

More broadly, Eyre and Baruah (2014) associated changing scenarios of the UK domestic heating transition with the increased ambition and urgency of overall energy policy goals. Before the CC Act, prominent energy scenarios forefronted the roles of energy efficiency, on-site renewables and CHP in reducing emissions (e.g. RCEP 2000; PIU 2002). Devised in the context of calls for 60 per cent decarbonisation of the UK economy by 2050, these early scenarios were based largely on the continuation of existing trends. Only after the CC Act was passed, with its commitment to '80% by 2050' decarbonisation, did the all-electric vision emerge. This vision was closely associated with economic optimisation modelling (often using MARKAL), with limited detail on the UK building stock and its compatibility with heat pumps; Eyre and Baruah (2014) argued that it was 'always treated with some scepticism in the building energy research community' (ibid., p. 8).

TABLE 4.2 Three low carbon UK domestic heating scenarios

Technology, share of UK domestic heating (%)	*Electric Heat & Transport Scenario*		*Local Energy & Biomass Scenario*		*Deep Decarbonisation & Balanced Transition Scenario*	
	2030	*2050*	*2030*	*2050*	*2030*	*2050*
Heat pumps	10	80	5	40	5	40
Micro-CHP	0.3	3	2	20	3	30
District heating	–	–	–	–	2	20
Biomass	0.3	3	3	30	1	10
Electric resistance heating	0.6	5	–	–	–	–
Reduction in building fabric heat loss (%)	-1	-5	-7	-30	-12	-50

Source: Eyre and Baruah (2014: 16).

In *any* credible decarbonisation scenario, Eyre and Baruah argued, the UK faced a disruptive heating transition, with major changes in supply chain practices and consumer experiences. Since early decisions could lead to path dependence and lock-in, divergent futures were possible, and a scenario approach was needed to map out the 'uncertainty space'. Using a combination of expert judgement and infrastructure modelling, Eyre and Baruah devised alternative plausible combinations of some key socio-technical variables, spanning not just the energy system but also wider socio-economic uncertainties.

Major differences emerged between Eyre and Baruah's scenarios after 2030, in terms of heating demand and technologies (Table 4.2). They concluded that while the future of buildings heating was likely to be a mix of electrification, refurbishment and biofuels (as biomass, biogas or district heating), the most compelling scenario was a *Deep Decarbonisation and Balanced Transition*. Like others, they recommended policy be aimed at opening up options and diversifying risk, but with more emphasis on neglected areas such as energy efficiency and biomass.

Summary and discussion

Changing visions: long-term transitions and short-term exigencies

The last half decade has seen a dramatic expansion of activity in UK energy futurology, with many scenarios of possible futures being set out, both from the policy mainstream and multiple other organisations. The trigger for much of this activity was the 2008 UK Climate Change Act, a remarkable statutory combination of commitment to long-term transformation and stepwise accountability. As part of this, heating for buildings has shifted from a largely unproblematic and invisible part of the UK energy system, to a highly active concern for policy, research and business communities. Over the course of a much expanded research effort on heating futures, scenarios of the UK's heating transition have changed substantially.

Despite the CC Act's profound long-term implications, however, the earliest mainstream energy scenarios devised in its wake had a short-term outlook – exigencies over the next decade preoccupied politicians and strategists more than decades-long transitions. This short-termism arose not from the CC Act directly, but from the interaction of CC Act-based efforts to meet early carbon budgets with other energy and climate policy initiatives, particularly the EU ETS and Renewable Energy Directive.

Guided by pressures for rapid change, prominent energy system scenarios devised soon after the CC Act identified two particular opportunities for change: the accelerated deployment of low carbon electricity generation technologies, especially renewables, and energy efficiency. Other parts of the energy system, such as buildings' heating, were seen in less urgent and secondary terms – indeed, they were less well represented in scenarios, given the limited analytical capacities and tools available at this time.

The 'all electric' vision for UK energy transition that emerged from these early scenarios was a rather simple blueprint, based on limited techno-economic research and modelling capacities which neglected many social, institutional and behavioural issues (Taylor *et al.* 2014; Watson *et al.* 2014). While this vision offered an apparently manageable and affordable pathway for system renewal, more marginal voices not committed to it, or persuaded by it, soon began to highlight its weaknesses.

As a wider set of business interests and research capacities gathered, the challenges of the UK's buildings heating transition were better understood, and faith in the all-electric future was eroded. Subsequent scenarios have tended to be less technologically radical, with greater technological diversity, including mature technologies or hybrid combinations of the old and new. DECC's Chief Scientist's call in 2009 for radical technological leapfrogging had, by 2014, been countered by a more technologically diverse and perhaps conservative vision.

At the same time, the purity of the UK's all-electric energy vision can be overplayed; even the early mainstream scenarios most closely associated with it contained many provisos, and recognition of the possibility of alternative outcomes. For buildings heating, they also identified the need for a lengthy period of experimentation and learning – in contrast with the accelerated deployment imperative for electricity supply and energy efficiency.

Modelling determinisms?

The rise of the UK's all-electric energy vision was closely associated with techno-economic optimisation modelling, and particularly the use of the MARKAL systems model in prominent mainstream scenarios. Taylor *et al.* (2014) attributed MARKAL's long-standing influence to its ability to serve shared policymaker and researcher interests, while ameliorating (at least for a time) political controversies and friction. However, although it remains a central and seemingly durable 'boundary object' in UK energy policy and research (Taylor *et al*. 2014), the present case suggests a trend to greater variety in the analytical tools and evidence bases informing energy scenarios, rather than an all-powerful MARKAL influence.

This said, in the early period following the CC Act there were claims for a determining role for techno-economic modelling in setting out an optimal techno-economic path, around which policy (and wider society) should conform. As well as reflecting underdeveloped analytical capacities to represent the multiplicity of energy transition challenges and opportunities, this perhaps also reflected the need to establish the legitimacy of the radical vision embedded in the CC Act. Within policy and research mainstreams, interpretations of modelled futures tended to be emphatic and definitive, leading to dissident criticisms of 'spurious accuracy', even from within government (pers. interview 2013). This determining role was never likely to withstand the contestations of liberalised political and research cultures, especially in much less benevolent economic times.

Indeed, rather than all-powerful 'pathway creation' machines, the present case suggests a more modest role for models, as embodiments of the prevailing views of some mainstream and marginal groups. Although it reflected the limited scope of models to represent alternative futures, the emphasis on a handful of large scale low carbon electricity technologies in many early scenario exercises were upfront design choices, rather than 'black box' modelling outcomes. Similarly, early mainstream scenarios for future heating were deliberately designed to restrict the role of some technologies (especially heat networks), while more recent scenarios have been designed to exhibit technology diversity.

A more legitimate accusation is that early scenario exercises after the CC Act embedded a false confidence about the affordability and manageability of energy system transition. In DECC's Carbon Plan, for example, low carbon innovation was seen essentially as a 'tame' and short-term problem, requiring only temporary interventions before technology choice was returned to market-based competition. That this was a systematic simplification and over-optimism about the challenges of low carbon innovation has since been revealed, under a combination of emerging evidence from field trials and early deployment, energy innovation research, and an appreciation of much changed investment conditions (Gross *et al.* 2013).

Changing policy and research cultures

Scenario exercises have long served organisational and institutional interests. Watson *et al*. (2014) criticised mainstream UK energy futures for their technocratic biases and their failure to properly address issues central to public framings. Kern (2012) accused UK energy policymaking more broadly of technocratic and supply-side biases, and called for a 'systematic uncovering' of the institutional biases involved. While the present case has found some of these biases and blind-spots, especially in early mainstream scenarios, the overall pattern is more mixed, with a relatively fluid set of interests and preferred futures. Nor was there any strong supply-side orientation: many UK heat scenarios emphasised energy efficiency and demand reduction – to an extent often not reflected in policymaking. (This suggests a role for scenarios as monitoring devices for policy adherence to longer-term commitments, in the face of system inertia and lock-in.)

The dilution of any single vision for UK energy system change in the period reviewed here reflects a shift from an abstract search for an 'optimal' scenario, to a more pragmatic and expedient focus on tractable ways of meeting policy targets. It also reflects the changing constituencies of policy and research communities, as energy and climate change has shifted from a technocratic niche to broader policy and research communities – with increased exposure to political, institutional and epistemological conflict (Meadowcroft 2009; Winskel and Radcliffe 2014).

While this has been a salutary journey for some mainstream research and policy groups, it can also be seen as demonstrating adaptability and learning in the UK's energy policy and research systems. As Anadón (2012) noted, one advantage of the UK's relatively weak and dispersed energy innovation system is its responsiveness to emerging evidence and shifting priorities; mainstream futures articulated since the CC Act have already proven much more contestable and malleable than the decades-long lock-ins seen in earlier periods in the UK energy industry (Russell 1993; Winskel 2002). In a liberalised and fragmented research culture, expertise and influence cannot be confined to technocratic elites, and the present case exemplifies the plurality of expertise and contestability of futures, with influential roles for industry associations and business consultants, as well as more traditional providers of knowledge in government departments and academia – a characteristic feature of the UK innovation style (Kern 2012).

At the same time, the dramatic revising of official energy futures in a few short years also betrays an unstable knowledge base. While expectations for some technologies have been dramatically cut back, others have risen to prominence. In part this reflects reference to a wider set of analytical tools and empirical evidence in more recent analysis, spanning field trial installations and stakeholder consultation, alongside an expanding range of system, sector and hybrid models (Dodds 2014). There is also some evidence of a trend to greater flexibility in interpretation of model results, with a recent emphasis on more diverse technology portfolios than a straightforward interpretation of modelling results would suggest.

This was not solely a process of learning within the policy and research mainstream: marginal counter-narrative scenarios were also influential. Indeed, some independent studies were advocating alternative futures at the same time as the all-electric scenario was being established in official thinking, and even within government, some marginal voices were offering counter-narratives (pers. interview 2013), but in the early part of the period reviewed here these carried little influence.

One distinctive aspect of the case reviewed here is the way in which some industry groups left marginalised by the mainstream all-electric vision, such as the Gas Networks Association and the Combined Heat and Power Association, responded by developing counter-narrative scenarios. While these alternative scenarios tended to reflect the particular interests of their industrial sponsors, the case suggests a constructive role, in research-policy exchange, for dissident visions which challenge the mainstream.

In conditions of high uncertainty, plausible futures can be constructed for many different outcomes and interests, highlighting the need to compare (and possibly synthesise) the findings of different studies, to assess the breadth and balance of evidence, and develop an 'evolving appreciation of whole' (Brewer 1999). One consequence of a relatively diverse policy and research culture is the difficulty of reconciling (or even making commensurable) different claims to the future. While this is ultimately a matter of public politics (Meadowcroft 2009) there is also a danger of selective references and biases in research and policy. Calls for pluralistic visions (Stirling 2011, 2014) rather sidesteps the need for accountable policymaking and long-term commitment for any large scale transition (Walker 2000).

Post technocratic whole system scenarios

While the future of UK heating for buildings has been framed here as an inherently whole systems problem, the case has revealed alternative and perhaps incommensurable versions of change. Although these differences are in part instrumental – in terms of differing system boundaries and component representation and ordering – they are also conceptual and normative, in terms of system constitution, governance and societal legitimacy.

In negotiating these issues, one lesson from the present case is the value of fostering a constructive interaction between mainstream and marginal futures. In addition, studies which have sought to systematically compare and synergise different studies have provided an important space for critical reflection on scenario processes and roles. One shared conclusion from many of the scenarios reviewed here is the need to 'keep options open', with a lengthy period of fostering diversity and learning – a long-standing finding in energy innovation studies (Jacobsson *et al*. 2004; Wilson and Grübler 2014). In practice, upholding this commitment in an energy sector infused with vested interests and policy exigencies is far from easy, and there are very different challenges for 'option creation' across different heating technologies.

This also leaves unanswered more fundamental matters of transition governance, often inherently political and value-laden, and which may not respond to accumulating evidence for their resolution. An overarching tension here is between market-based governance as articulated in many mainstream scenarios, and more active transition management as suggested in some alternative scenarios. While this tension can be overplayed – UK energy governance has moved to a 'messy middle ground' between markets and state direction in the period reviewed here – assembling future socio-technical heating systems at scale will involve a considerable level of co-ordination between market actors and public policymakers.

One policy and research response to urgency and uncertainty is a retreat from whole systems analysis, with recourse to more partial framings and at-hand solutions. Whole systems scenarios will always be limited exercises in futurology, undermined by emergent uncertainties, shifting policy commitments and contested politics, and efforts to establish an evidence-based 'optimal' path will remain a technocratic chimera. Despite these limits, however, there is an important role for whole system scenarios as part of good governance, in articulating and testing the varied assumptions, analysis and interpretations involved in claims about the future.

Notes

1 Although the focus here is on the UK energy system scenarios, there is now a number of heat scenarios at different territorial and governance scales, both within the UK (e.g. Scottish Government 2014) and internationally (e.g. Euroheat & Power 2013).
2 While the main analytic focus here is on different visions of UK buildings heating futures, a clear distinction between buildings heating and industrial heating, and between heating and power, is often not maintained in scenario studies – indeed, assessing the prospects for CHP/DH *requires* an integrated vision of heat and power supply and use, across domestic, commercial and industrial sectors.
3 The MARKAL ('market–allocation') model is an economic optimisation model that devises possible future energy system configurations based on detailed assumptions about technology cost and performance and energy service demands. It has played an important role in UK energy and climate policymaking since 2002 (Dodds *et al.* 2014), and in UK and international energy research (Skea *et al.* 2011b; IEA 2014). For critical reflections on its use, see McDowall *et al.* (2014) and Taylor *et al.* (2014).
4 Dodds (2014) also highlighted the limited representation of hydrogen-based technologies, such as fuel cell micro-CHPs, in many heating scenarios.

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5

IMPLEMENTATION OF DISTRICT HEATING POLICY IN THE UK

David Hawkey

Introduction

This chapter discusses policies adopted in the UK to support district heating. Two quotes from the UK Secretary of State for Energy and Climate Change (Ed Davey) illustrate core themes of this chapter. The first quote is taken from the foreword to the 2013 Heat Strategy published by the Department of Energy and Climate Change (DECC):

> there has been a historic failure to get to grips with one enormous part of the energy jigsaw; the supply of low carbon heat. … [We have] inherited a big hole where there should be policy for finding alternatives to fossil fuel for the supply of heat.
>
> *(DECC 2013: 1)*

The supply of low carbon heat, and development of heat networks specifically, has, since around 2012, come to occupy a prominent position in both UK and Scottish policy (see Chapter 4). Whereas previously heat supply had been an add-on to other policy areas such as biomass (cf. Scottish Executive 2007) or the thermal efficiency of buildings (cf. DECC and Department for Communities and Local Government 2009), it is now an institutionalised policy area in its own right. This is evidenced by the creation of policy divisions, government partnerships, policy strategies, statements, visions and targets focused on heat networks (DECC 2013; Scottish Government 2014). However, the picture of a 'big hole' in earlier policy is misleading if taken to mean government has previously not attempted to stimulate development of district heating in the UK. In this chapter we situate discussion of current policy in the context of these earlier programmes and the ways they shaped district heating systems.

The second quote is from a speech to a conference on heat organised by a district heating industry association in 2012:

> … we are already helping cities to develop their plans for district heating. Central government is not going to build their networks for them, clearly. But we know … that a small amount of help in the initial phase of a project can go a long way. It can help to move projects to the point of commercialisation – where the Green Investment Bank and commercial lenders can take up the reins, investing in heat network projects with profit-making potential.
> *(Davey 2012)*

The commitment that central government is not going to build heat networks, 'clearly', reflects a broader issue that responsibility for developing heat networks is not clearly located with *any* actor in energy policy. Instead policy depends on a form of voluntarism, relying on local actors, particularly local authorities, to set objectives and identify opportunities. Whereas the large scale heat networks in European cities discussed in Chapter 3 were regarded as solving critical problems confronting local actors, in the UK objectives and opportunities tend to focus on limited groups of buildings, often under the control of a single organisation. Heat networks thus tend to develop in a fragmented manner and be small scale, failing to exploit the scale economies of larger systems (Chapter 6). We argue this issue has been exacerbated by constraints imposed by government policy.

The reliance on commercial actors to 'take up the reins' of heat network development is another important theme. Dependence on commercial finance introduces tension with social and environmental objectives. Furthermore, while it has long been a stated aim of UK energy policy 'to provide industry and investors with a clear and stable policy framework' (Department of Trade and Industry 2003: §2.22), experience from the perspective of heat network developers has been of unpredictability in policy in two senses: uncertainty, in that the impacts of policies commonly depend on a series of intersecting contingencies which are difficult to calculate *ex ante*; and flux, in that policy can change over relatively short periods, incompatible with long-range planning for the development of city-scale heat networks.

Finally, the 'small amount of help' government offers cities takes a particular form, focusing on providing knowledge and skills to local authorities. It does little to strengthen their capacity to recruit and coordinate a large user base, a second factor we argued in Chapter 3 has been important in the construction of large heat networks in European cities. Thus, while the poor performance of small networks relative to larger systems is recognised, policy does not establish mechanisms to build more extensive systems.

The chapter draws on analysis of a range of sources gathered between 2010 and 2014. In addition to historical and contemporary policy documents and reports, it includes interviews with 16 officers of the UK Government, the Scottish Government and non-departmental public bodies, as well as a broader set of interviews with 145 commercial and public sector district heating practitioners. The authors' participation in four 'District Energy Vanguard Network' knowledge exchange events with local authorities and UK and Scottish governments is also drawn on.[1]

Government funding programmes for heat networks

In this section we draw comparison between current policy approaches to heat network financing and three earlier programmes: the *Lead Cities* programme that emerged in the wake of the 1973–74 oil crisis; the *Community Energy Programme* that developed during the first years of the twenty-first century as climate change was first becoming a central part of energy policy; and the *Low Carbon Infrastructure Fund*, which was part of a green stimulus to support demand in the UK economy. Current heat network policy is complex, but the principal vehicles that the UK and Scottish governments have introduced for heat network financing are the *Green Investment Bank* and the *Renewable Energy Investment Fund*. We first introduce these programmes before analysing their impact.

The Lead Cities programme emerged from proposals made in 1979 by a committee chaired by the physicist Walter Marshall to investigate energy conservation in the UK. The committee calculated that, although prevailing heat and power prices at the time meant large scale combined heat and power (CHP) and district heating schemes would not be economical in the near term, their primary energy savings would become important as oil and gas became more scarce in future. It therefore recommended a programme of demonstration schemes and the establishment of a National Heat Board to coordinate activities (Babus'Haq and Probert 1996).

The formation of a new state entity to plan and oversee construction of city-scale heat networks echoes the establishment of the Danish Energy Agency around the same time (see Chapter 3). However, in the UK expanding the scope of state participation in the energy economy was politically unacceptable to the incoming Conservative Government of 1979. The National Heat Board was never established, and instead the programme was reformulated as a competition between local authorities for grant funding to develop schemes able to attract private investment. Nine authorities prepared plans but found action by central government to be limited, both in terms of supportive policy and funding. Three cities (Leicester, Belfast and Edinburgh) eventually received small amounts of funding in 1985, and three additional cities (London, Sheffield and Newcastle) pursued their plans in spite of central government deciding not to offer funding. What had initially been conceived as a programme supported by the state in spite of conditions of unfavourable heat and power prices became a series of frustrated attempts to mobilise commercial finance into those same conditions. Results varied across cities, for example a sizeable (by UK standards) network was developed in Sheffield, a patchwork of small unconnected networks in Leicester (see Chapter 8), and nothing in Edinburgh.

After a hiatus in the UK Government's interest in district heating of some 15 years, it launched the Community Energy Programme (CEP) in 2001. The programme was part of a wider *Capital Modernisation Fund* established by the UK

Treasury in response to what it analysed as underinvestment in the public estate by previous governments. The £50 million programme combined grants for technical studies with capital grants up to 40 per cent of the costs of new, refurbished and expanded heat networks, and CHP systems. Funding was available to public sector organisations, and supported development of some of the UK's most influential projects, including heat networks in Lerwick, Aberdeen, Birmingham and Woking. However, the programme struggled to meet its objectives, eventually spending £29m in capital grants for 57 projects with a total capital cost of £93m, and a further £1.9m in grants for 140 technical studies (Department for Environment, Food and Rural Affairs [Defra] 2007). In 2006 the Government abruptly announced the closure of the programme amid concerns that the programme's targets (relating to carbon, cost saving and affordable warmth) were unlikely to be met.

After another gap of three years, a new programme was created in 2009 with little notice. The £26m Low Carbon Infrastructure Fund (LCIF) was announced by the Treasury in its 2009 Budget as part of a wider stimulus package established to support demand within the economy in the wake of the global financial crisis of 2007–08 (UK Treasury 2009). It intended to support at least ten heat network schemes in England. The Homes and Communities Agency (HCA, England's housing and regeneration agency) administered the fund as a partnership with the Department for Communities and Local Government and the newly formed Department of Energy and Climate Change. Funds were allocated to local authority applicants over a very short period: £21m to 13 schemes between April and November 2009 with the remainder subsequently allocated to three additional projects. As part of an emergency economic stimulus package, the LCIF was a one-off fund and not repeated in subsequent years.

The UK's Green Investment Bank (GIB) was established three years later in 2012. The GIB aims to support commercial financing of a range of technologies, including heat networks. In the wake of the 2007–08 global financial crisis and subsequent recession, the UK Government considered the costs of 'green infrastructure' required to meet its greenhouse gas targets, calculated as running to hundreds of billions of pounds by 2025, to be far greater than the sums available from utility companies, project finance and infrastructure funds (UK Parliament Environmental Audit Committee 2011). Inspired by the German KfW development bank, various proposals for a UK Green Investment Bank circulated from about 2009. The institution would initially be capitalised from public funds, and debate centred on the extent to which its operations would be characterised as a 'fund' (i.e. be restricted to using the initial capitalisation) or as a bank (able to raise further finance through issuance of 'green bonds'). An incoming Conservative/Liberal Democrat Government in 2010 set elimination of the state's budget deficit as a central goal. Additional debt incurred by the bank would be incompatible with this goal, and borrowing powers were withheld pending reductions in public sector debt (Department for Business Innovation and Skills 2011). The bank thus initially (and at the time of writing) operates as an investment fund. Alongside the GIB, the

Scottish Government created a Renewable Energy Investment Fund (REIF) which operates in a similar manner to the GIB, and includes heat networks using renewable heat sources as a priority area.

Programme objectives and the scale of heat networks

The objectives which central government has set for district heating varied across the programmes, with significant consequences for the configuration of networks that emerged. Under the original proposals for the Lead Cities programme, the objective was to use the efficiency of CHP to reduce national exposure to resource shortages. This overarching objective was not tied to any particular group of heat users, but was calculated to be most effectively achieved by large scale heat networks in cities, paralleling the Danish and Swedish use of heat networks to alleviate oil dependency discussed in Chapter 3. However, when the Lead Cities programme was translated into practice, its objectives appeared to change: Russell (1994) concluded that DH and CHP were treated by the 1979 Government as a test bed for the emerging approach to energy under which markets would determine whether the technologies were 'worthy', rather than centralised planning by public agencies. The emphasis on private finance meant heat networks were appraised in terms of short-term financial returns rather than mitigation of dependency on particular primary energy sources. Financial viability was made more difficult to achieve given the Government's apparently ambivalent position which raised investors' perception of risk and hence the returns they required.

Objectives of subsequent programmes have not tended to result in efforts to develop large scale heat networks. The CEP was funded from the UK Treasury's Capital Modernisation Fund, which was part of on-going efforts to 'modernise' public services. Modernisation here had two senses: the facilities and other assets which underpinned public service delivery were perceived to have suffered a period of underinvestment under political mismanagement, and would be brought up to 'modern' standards; and the way public services were managed and delivered, perceived to have been inefficient, and would undergo various reforms, including changing to 'modern' accounting practices (UK Treasury 1998).

The first sense of 'modernisation' directed the programme towards investment by public sector organisations in their own buildings. To the underlying modernisation objective the Government added alleviation of fuel poverty and climate change mitigation. The fuel poverty objective was associated with specific building, high-rise flats, where the main alternative to district heating was expensive electric storage heaters, and where the density of heat demand was high. While the objective of mitigating greenhouse gas emissions was not in principle tied to specific kinds of building, projects funded under the programme tended to focus on specific clusters of buildings which could be coordinated. Hospitals and Universities used funds to build heat networks serving their campuses, or to upgrade existing schemes to CHP.

The focus on specific groups of buildings rather than city-districts or more general interventions in the energy sector has continued to be a feature of heat network development in the UK. For example, social housing landlords have been required by Government to improve the energy efficiency of their stock, and have in some cases achieved this drawing on subsidy programmes targeting low-income areas. Some schemes have sought to build larger and more diverse user bases, but reliance on voluntary coordination across organisations often thwarts such projects (see Chapter 7).

Coordination difficulties have been exacerbated by the timescales imposed by funding programmes. Under the CEP, the time it took to develop district heating projects was regarded (in Defra's 2007 evaluation) as a 'huge eye opener', the programme's deadlines reflecting limited experience of community energy in the period prior to CEP. Various causes of project delay were experienced, including securing planning consent, financing and management issues, and difficulties and uncertainties in complying with State Aid rules and procurement processes (see Chapter 6). In response, Treasury granted extensions to the programme, first to 2005, then 2008. In 2006 the Government had a change of heart and cancelled the programme.

By the time the programme was cancelled 36 of the 93 schemes to which grants had been allocated had dropped out. Those progressing tended to be relatively small: 40 per cent of schemes dropped out, but these represented 55 per cent of the grants allocated by value.[2] It was the larger, more ambitious schemes that failed, proving too complex to handle within the CEP timeframe (see Figure 5.1). LCIF, being an emergency stimulus package, imposed even tighter timescales, requiring funds to be committed within a year, again making complex projects difficult to secure (HCA 2010).

The scale of heat networks developed under these programmes was consequential for their overall effectiveness. Large district heating systems can exploit various economies of scale and scope (see Chapter 6), so the concentration of the CEP into small schemes with relatively homogenous groups of users meant projects 'tend[ed] to be expensive in relation to their outputs' (UK Government 2006: 88). Indeed, in announcing its decision to cancel the CEP the Government acknowledge that its own timescales prevented the development of more cost-efficient schemes, noting that some of the large schemes would not complete before 2010 (four years later), a timescale then deemed unsuitable for government funding.

Programme objectives and judgements of heat network viability

The second sense of 'modernisation' that underpinned the Capital Modernisation Fund, of which the CEP was part, related to the ways public sector organisations accounted for current and future costs. New accounting rules adopted across government sought to eliminate perceived perverse incentives on public sector managers to minimise near-term costs without sufficient regard for longer-term consequences. Correspondingly CEP guidance to public sector applicants

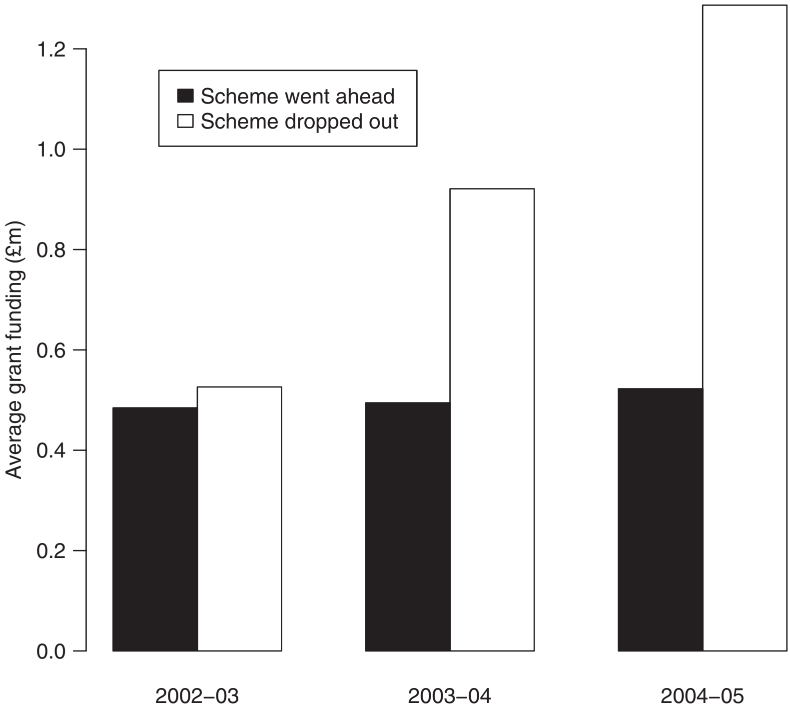

FIGURE 5.1 Average size of grant for schemes progressing and schemes dropping out under the Community Energy Programme.

emphasised a shift 'away from assessing options in terms of which provides the least capital cost option, towards the option that provides the least cost solution over a lifetime' (Energy Saving Trust and Carbon Trust 2003:1). Time-discounted cost-benefit analysis was thus used to award CEP grants to projects whose projected benefits outweighed costs using the Treasury's social discount rate of 3.5 per cent per year over 25 years. The 'whole-life cost' approach to appraising district heating was instrumental in reshaping the way grant recipients appraised technology options, with heat networks being judged more favourably than under previous approaches (see Chapter 7).

CEP grants were offered for up to 40 per cent of capital costs, with applicants encouraged to draw on commercial finance for the remainder. In the event schemes used a mixture of commercial finance, other grants and local authority budgets, with commercial finance more common for campus schemes (universities and hospitals) where heat demand was more secure than housing and other public sector projects (Energy Saving Trust and Carbon Trust 2003).

Whereas the CEP used financial criteria to direct grants into modernising public sector assets, LCIF as part of an emergency economic stimulus package used other criteria to justify spending. The HCA sought to find 'shovel ready' projects which its funding could make happen, and from which 'lessons could be learned'. Both CEP and LCIF, therefore, were used to plug shortfalls in project financial packages. By contrast, the GIB and REIF are designed with the *creation of investment markets* for sustainable energy as their central rationale. An estimated £330bn investment is required by 2020 to meet UK climate and energy objectives (GIB 2014), a vast amount of money when set against the £3.4bn and £103m capitalisation of the GIB and REIF respectively. With no borrowing powers to augment this capitalisation, GIB and REIF are tasked with using their funds in such a way as to stimulate self-sustaining commercial investment markets, which would allow public funds to be withdrawn and redeployed in other sectors. Whereas the grants disbursed under CEP and LCIF were *ingredients* added to projects to make them financially viable, public finance in GIB and REIF is a *catalyst* for creating markets in financially viable projects.

This distinction has far-reaching consequences for the characteristics projects must display to receive support. GIB and REIF require projects to meet the investment criteria of private finance, but for which public co-investment would overcome attributed market barriers. In the GIB's idiom, it aims at 'crowding-in additional finance, not displacing other investors' (GIB 2014: 14). In consequence the funds are careful not to provide finance that would be perceived as undercutting commercial investment. A number of rationales inform this position: if a sector became dependent on low cost GIB finance, the bank would be construed as having failed to create a market from which it could exit; where GIB money is invested via investment funds, co-investors may perceive the presence of a sub-commercial component as 'dampening returns' and creating pressure to invest in 'flaky projects' (interview with GIB officer 2012); and one of the GIB's objectives is to generate profits to feed back into public finances. Compared with the CEP's appraisal at 3.5 per cent discount rate and LCIF's emergency spending character, GIB funded projects will be required to generate cash flows with significantly higher returns. Projects that would have been viable under previous programmes may not meet the GIB's criteria.

The GIB's objective of supporting low carbon district heating cuts across different kinds of buildings, and so is compatible with projects not structured around particular kinds of user. However, orienting support to schemes which maximise financial returns may lead to 'cherry picking'. A common approach to building large district heating systems is to initially connect up buildings with high heat demand (such as hospitals and hotels). These 'anchor loads' provide steady revenues to the initial heat network which can then be extended to smaller users (see Chapter 6). However, this second step may not increase financial returns, so an emphasis on profit-making may result in only the initial anchor loads being connected. As one local authority officer puts it:

> there are examples across the country where networks have been put in, some of them in partnership with utilities where they put a lot of the public sector buildings on and then they said, 'Oh, we'd like to connect up to this area of

> social housing because it's part of what we do' and they went, 'Oh there's no money in it, you're not connecting, we own a majority share.' And they're lost.
>
> *(Local authority Sustainable Development officer, interview 2012)*

Impacts of programmes on district heating industries

While CEP and LCIF grants plugged gaps in financial viability, they also sought to 'pump-prime' market development. Consultancy and contractor services for district heating and CHP were regarded as something of a 'cottage industry' at the beginning of the twenty-first century. Prior to the CEP government estimated turnover in the industry to be about £15m/year, a figure used to illustrate the relative significance of the programme and to argue that it would stimulate further development of skills and supply chains, with consequent lowering of costs (UK Parliament House of Lords Science and Technology Committee 2005).

However, industry had been given little foresight of the CEP and, when initiated, it was unclear whether further support would be available after the 2005 spending deadline. Consequently industry did little to build its capacity further. In the event, rather than leading to lower costs, the glut of demand for consultancy and contractors created by the programme worsened conditions. Ironically, rather than 'pump-priming' markets the effect of the programme was to raise prices and lengthen lead times, consequences which further contributed to government's calculation of poor cost effectiveness (Defra 2007). The emergency spending character of LCIF likewise meant it had little impact on any systematic and coordinated development of the sector.

Getting scale into the market

Scale is an important dimension to the GIB's approach to heat networks. Institutional investors, such as pension funds and sovereign wealth funds, are construed by GIB officers as the 'end game' for GIB investment, offering large volumes of long-term finance in exchange for reliable returns at lower interest rates than other investors. These investors have minimum investment sums, below which transaction costs are deemed unwarrantedly high. For district heating this means:

> Somehow you've got to get scale in this market, so if you're thinking ten, twenty million pounds, that's not going to be exciting to anybody in the private sector, you really need to be getting to fifty or a hundred million or maybe more than that.
>
> *(Green Investment Bank officer, interview 2012)*

Most heat networks developed in the UK are much smaller than this. For example, total capital investment under the CEP was £93m spread across 57 projects, the largest project representing £6.9m. As argued above, district heating schemes in the

UK have tended to focus on specific users, where local objectives and organisational control over buildings combine. Debate on how the GIB can solve this issue focuses not on expanding the scale of individual heat network projects (i.e. by drawing large numbers of heat users onto each scheme), but on aggregating multiple projects into a single financial package.

Such aggregation has not yet been attempted in the UK, but it would shift a coordination problem from the local level (coordinating multiple users) to a national level (coordinating multiple projects). The approach would require a degree of standardisation without which transaction costs would be too high. Standardisation would also fit assumptions government makes about the role of experience in investors' decision making. The assertion is that investors calculate risks and returns on the basis of a set of standardised cases, so the absence of a record of comparable UK cases leads them to 'invest less than the optimal amount' (Department for Business Innovation and Skills 2011). A further concept used within the GIB initiative, therefore, is 'deal flow' – creating a series of standardised projects from which investors can draw knowledge.

These pressures for standardisation stand in tension with the range of local priorities and variety of business models currently adopted by local actors (see chapters 6 and 7). Local authorities active in heat network development argue that standardisation would stifle innovation, and undermine their capacity to negotiate locally specific arrangements with contractors (Hawkey *et al.* 2013). This is significant as such negotiations are regarded as important means by which local authorities can ensure the most commercially attractive heat network opportunities support extension to other users, rather than being 'cherry picked'. Furthermore, once a local project is packaged together with projects elsewhere as a financial vehicle, it may become difficult for local actors to change a project in response to evolving local circumstances. Other areas of public service which have been packaged as financial products for commercial investment, such as the UK's Private Finance Initiative, have been found to reduce discretion of public authorities to deviate from contractually agreed activities (Froud 2003; see also Chapter 7).

Fluctuating market and policy conditions

District heating initiatives intersect with energy prices and a range of government policies beyond capital support programmes. Uncertainties in these domains can have an important bearing on judgements of viability and the willingness of organisations to explore shared schemes (see Chapter 7).

For example, changing market conditions in the early 2000s contributed further difficulties to the CEP in meeting its targets. Simultaneously the price of electricity fell and gas prices rose, reducing the crucial 'spark spread' and meaning CHP schemes would face higher costs but generate lower revenues than had been anticipated when the programme was designed (Helm 2004; Kelly and Pollitt 2010). Schemes thus tended to require a larger proportion of grant funding than the programme's design had anticipated (Defra 2007). With hindsight the depressed spark spread is now regarded as having been temporary, rising again after 2005 (Kelly and Pollitt 2010). Projects that did proceed have been able to generate considerable income or savings since then. However, CEP grants were awarded on the assumption that then-current prices would be fixed over the scheme's lifetime.

The squeezed spark spread was an unpredicted outcome of a number of changes in UK energy markets, including the on-going process of liberalisation and regulatory changes to electricity trading (Helm 2004). Other forms of unpredictability that have affected district heating development in the UK are more directly related to decisions made by central government. Often these decisions are concerned with tackling problems unrelated to district heating, but are nonetheless consequential.

For example, in 2009 the Government announced the CHP exemption from the *Climate Change Levy* (CCL) would be extended an additional decade to 2023. However, the very next year, government proposals to reform the CCL were introduced. The aim of the reform was the carbon price faced by mainstream (electricity-only) generators, but the Government argued that for administrative simplicity CHP would be included, meaning its exemption from the CCL would be withdrawn in 2013. The CHP industry lobbied against the decision, and in its 2014 budget, the Government decided to offer exemptions to CHP from the new mechanism (UK Treasury 2014). While the outcome of the process may not have damaged CHP-reliant district heating schemes as significantly as the initial proposal would have, it created a four year period of lobbying and uncertainty.

A second example concerns obligations imposed on energy companies to pay for energy efficiency measures. Companies pass the costs of meeting the obligations on to their customers (Guertler 2012). The latest incarnation, the Energy Company Obligation (ECO), began in 2013 and included district heating as an eligible technology in particular circumstances, for example where solid wall insulation was installed at the same time. However, in November 2013 the six main UK energy companies began a round of price rises, bringing average domestic bills to levels almost 40 per cent higher than they had been in 2010. By comparison average earnings had increased over the period by just 4.4 per cent (Citizens Advice 2013). Under pressure to mitigate price rises, and amid media reports that the Prime Minister had instructed aides to 'get rid of all the green crap' from energy bills (Mason 2013), reforms to ECO were abruptly announced. The broad ECO carbon target was reduced by a third, reducing energy company spending across the energy efficiency sector. Further changes emerged through a consultation process, including a degree of relaxation in eligibility constraints (for example, solid wall insulation was less critical to heat network eligibility, DECC 2014a). The combined effect on district heating of reduced targets and relaxed heat network eligibility is difficult to estimate (not least because, being a market-based mechanism, the outcome of ECO before and after the reforms are intentionally left to competitive processes to determine).

These examples illustrate ways district heating has been buffeted by policy decisions targeting issues not directly related to heat networks. The marginal position of district heating in policy decisions affecting it may be a reflection of the fact that at present district heating accounts for around 2 per cent of heat demand, a tiny fraction of the UK's broader energy systems. In both cases, the eventual outcome may not have been financially detrimental to prospective district heating business models, perhaps reflecting a growing concern with district heating in energy policy. However, the periods of uncertainty created by policy fluctuation were disruptive to the complex and lengthy processes of project development, and some practitioners claim prospective schemes were abandoned during these periods.

The role of local authorities in district heating policy

Local authorities are accorded important roles in national policy, DECC's 2013 Heat Strategy identifying them as 'critical players' (DECC 2013: 50). In addition to potentially sponsoring projects, they are regarded as able to create a 'supportive environment' for heat network development through their responsibilities for planning, urban regeneration, housing and roads; their social housing and other buildings which can be connected to heat networks; their ability to undertake various local analyses to identify opportunities; and their scope to broker agreements between various local parties and heat suppliers.

In this section we explore how central and devolved governments seek to support local government to 'make the best use of their unique position' (DECC 2013: 50). Broadly, policies aim to facilitate local authorities in developing local projects and strategies by mitigating knowledge and skill deficits, and in this sense increasing local government capacities relating to district heating. However, we argue that these interventions do little to overcome weaknesses in local authorities' capacity to coordinate the connection of large numbers of users to local heat networks.

Heat network support services

Both Scottish and UK governments established support services in 2013 for public sector organisations (mainly local authorities) engaging with DH development. The Heat Networks Delivery Unit (HNDU) in UK DECC has a budget of £9m to disburse as grants to local authorities in England and Wales to support development work for heat networks but not capital spending. Support is only available to cover external costs (i.e. consultancy work) rather than any in-house costs. The Scottish Heat Networks Partnership (HNP) brings together a range of government agencies charged with supporting public sector organisations in developing heat networks.[3]

The two support organisations have similar objectives, but operate in different ways. HNDU is a dedicated support unit, whose internal team of specialists guide local authority officers through a range of processes involved in developing heat network projects, including procurement of feasibility studies, development of local plans, and engagement with potential contractors or delivery partners. HNP coordinates existing support services, supports knowledge exchange among practitioners and has created shared knowledge resources such as case studies and guidance documents. HNDU disburses a pot of grant funding, while HNP helps Scottish organisations access external funding (such as European grants) and may commission consultancy work on behalf of local actors. Capital funding is also available to Scottish projects in the form of low interest loans.

Both services are similar in relying on local authorities voluntarily engaging with district heating. The support services address knowledge and skills gaps, but it is for local authorities to decide how to use these resources. HNDU is explicit on this point, it gives local authorities guidance (points for consideration) rather than advice (advocacy of a particular course of action): responsibility for decisions is located with the local authority rather than the support unit (DECC 2014b). In part this is a symptom of government reluctance to place binding requirements on local authorities to develop heat networks. From the perspective of the UK and Scottish governments the voluntaristic approach is perceived to have various advantages. Imposing additional burdens on local government is regarded as difficult without accompanying funding, and would run counter to prevailing orthodoxies that local government should be under *less* central direction from other levels of government. The approach may afford greater flexibility than a central directive to all authorities, but it has drawbacks. Local authority officers interpret the approach of central government as failing to establish a *mandate* to engage in development of energy systems, particularly beyond their own estates (Hawkey *et al.* 2013). In a context where other local authority activities *are* mandated by central government, and with pressures on budgets, local engagement with energy occupies a difficult position even for the most active authorities (see also Chapter 8).

Local and national heat mapping

Heat maps present heat demand data spatially, and can be used to inform judgements as to where to develop heat networks. Both UK and Scottish governments have invested in creation of heat maps covering England and Scotland respectively. These decisions to develop a heat map at a national level followed from abortive attempts to encourage local authorities to create their own heat maps. In England 2007 planning guidance required authorities to develop an evidence base for identification of decentralised energy opportunities (DCLG 2007), though responses were patchy and of variable quality. A slightly different approach was adopted in Scotland, with a national *methodology* developed through a pilot with Highland in 2011. However, local authorities do not hold the required data on buildings in their area, which is instead controlled by 14 'assessors', creating administrative difficulties. Rather than rely on the local authorities (whose levels of enthusiasm for the exercise varied) to collect and process the data, in 2013 the Scottish government undertook this work directly.

National-level heat mapping has several advantages from a national perspective: quality assurance, efficiency of effort, comprehensive coverage, and overcoming some of the limitations faced by scenario modelling (Chapter 4). However, the shift from local mapping to a nationally developed resource has consequences for what function the maps perform. If local authorities are conceived of as singular and cohesive entities, a heat map may be understood as a knowledge resource supporting rational development of plans, policies and investments that achieve the authorities' objectives. However, local authorities are complex organisations and heat networks have implications for a range of objectives which are commonly embedded in different departmental structures. Describing his experience developing a heat map within a local authority, one local government officer noted that the process was an important part of establishing a common understanding across departments:

> I went to planning and talked to them and got them engaged with how it would work. I got economic development engaged and after a while we kind of realised the real economic value of heat, potentially for **generating** income and for sustaining economies within your local area. And of course fuel poverty was something I knew about anyway. … [I showed] the heat map back to the managers, who then looked at me and said, 'Did you see in that what we're seeing in it now because we didn't when you told us about this wacky idea a long time ago.' And I said, 'well, partly', … I kind of knew that a pictorial thing which brought agendas together in a spatial way but had data beneath it was a very powerful tool. And if you could get people to understand themselves and what they understood within that and how it related to these other needs you could then start to talk about a coordinated approach to something which is a fundamental thing which heat needs.
>
> *(Local authority Sustainable Development officer, interview 2012, bold indicate vocal stress)*

The process described here was thus valued by the officer not only as a means of drawing colleagues in to supporting the heat map, but also as exploring what local issues heat mapping could actually contribute to addressing. That is, rather than the heat map being positioned as a product to be consumed by different departments, the process of engaging different parts of the authority with the map's development generated locally conditioned meanings of heat mapping and, in the view of the officer quoted, a broad based sense of ownership or buy-in across the authority for pursuing projects that emerged from the process. While decisions to centralise heat mapping were in part a reaction to the variable response across local authorities (i.e. not all had officers as enthusiastic as the individual quoted above), taking the process out of local control arguably undermines one route to embedding heat network development across a local authority's activities. As one consultant observes,

> It's now just a resource that they have that [the local authority] can talk to developers about. And that's the way the heat map is seen, it's not seen as a

> strategic tool for the council to develop what happens. It's seen as a tool that the university can use to say 'where else can we connect our heat network to?', and I think that needs to be seen in a different way.
>
> *(Energy specialist, international engineering consultancy, interview 2013)*

Local authority capacities to coordinate a user base for district heating

The failure of the more complex schemes under the CEP highlighted the absence of effective mechanisms to recruit multiple users to a single new heat network. In response, the UK Government introduced new guidance, aiming to use the spatial planning system to support the establishment of heat networks beyond local authorities' own buildings. The guidance permitted English local authorities to require new developments to connect to heat networks (DCLG 2007). Similar guidance was introduced in Scotland and Wales, but in all three cases no indication was given as to how decentralised energy related to other planning objectives with which it may conflict, resulting in limited uptake (Williams 2010).

Nevertheless those authorities actively pursuing decentralised energy regarded the guidance as significant in bolstering local planning policy. In 2012 UK Government planning guidance was however reformed to comprise much shorter, less detailed material. Through the institution of new 'neighbourhood plans', communities were enabled to take some planning powers from local authorities. Authorities which had developed district energy planning policies found the reforms undermined their capacity to use planning powers to support heat networks, with some describing the new system as a 'shipwreck' (Hawkey *et al*. 2013). In the same year, a civil servant from the UK Government Department for Communities and Local Government explained to an industry group that the impact of the reforms would only become clear over time (possibly years), as the new guidance and institutions settled – opportunities would be neither clear nor consistent, and practitioners would have to work under uncertainty. The parallel with energy policy is clear: the peripheral status of heat networks means their development is buffeted by unpredictable changes driven by mainstream concerns.

In the absence of reliable powers to establish larger, more complex schemes, some local authority officers seek to use large public sector buildings to leverage investment in more extensive networks. Rather than allow their buildings to be 'cherry picked' by commercial heat network developers, some authorities discuss using the commercial attractiveness of supplying heat to the public sector to negotiate supply to other, less attractive users. A local authority planning officer describes an envisaged joint venture thus:

> with the public buildings, with the campuses, with these buildings which you know have a constant heat requirement … that's really quite a valuable asset

> and … we need to make sure that through this discussion with this potential company being set up that there is a recognition that that is something we need to carefully trade and use to our benefit. … There's got to be something for them, ultimately they want a commercial return. So for it to start really making economic sense you've got to, you know, God it's going to be an incredible game of poker, just how much we can get for those assets and it's fantastic that the thinking is linking it directly to the affordable warmth agenda.
>
> *(Local authority planning officer, interview 2012)*

Examples of local authorities successfully playing their hand in this kind of poker game are yet to emerge. While success is not unimaginable, the approach introduces another layer of risk to the realisation of local objectives, namely whether the local authority is successful in its negotiation. The discussion of heat network development in Amsterdam in Chapter 3 suggests on-going tensions between commercial and social objectives can be difficult to resolve, particularly where the local authority perceives their partner to have greater access to relevant commercial information. Furthermore, to the extent that such negotiation relies on local authorities exploiting locally specific circumstances, the approach may be undermined by the forms of standardised mechanisms envisaged around GIB finance discussed above.

Conclusions

The proposals for the Lead Cities programme at the end of the 1970s set out a vision for city-scale heat networks, analogous to similar policy visions articulated in Sweden and Denmark. When translated into practice, however, the public planning and expenditure implied by the proposals were unacceptable to UK Government, and instead a funding competition was organised with fewer, and generally smaller systems developing than had originally been envisaged. While policy interest in district heating has waxed and waned since the turn of the century, and appears to be currently gaining momentum, district heating development has continued to have a fragmented character, with small networks connecting specific groups of buildings, and little development in the scale of consultancy and contractor industries. In part the fragmented character relates to difficulties planning large systems and brokering a complex of multi-organisation agreements in the face of fluctuating conditions: unpredictable movements in energy markets, dependence on policies which may be suddenly changed in response to problems unrelated to district heating, and abrupt introduction and cancellation of funding programmes. In part the fragmented character relates to the limited capacities of local authorities, or any other local actor, to recruit and coordinate others to a heat network, an issue which government policy has tended not to address. And in part it relates to the objectives around which heat networks are constructed which tend to relate to specific buildings: fuel poverty objectives focus on high-rise social housing while commercial objectives orient towards clusters of large public-sector buildings with risks of cherry-picking.

The specificity of heat network objectives appears in tension with the far-reaching decarbonisation targets adopted in the UK which are 'likely to require reducing emissions from buildings to near zero by 2050' (DECC 2013: 5). Decarbonisation objectives, in common with the original objectives of the Lead Cities programme, are general across buildings which require heating. Why, then, does policy not currently translate the decarbonisation objective into a programme of much larger scale heat networks? One reason we suggest is the divergence of scenario analyses discussed in Chapter 4, meaning government has not formed a clear vision for the extent to which district heating should be deployed. Furthermore, establishing and pursuing such a vision would run counter to policy preferences for passing decision making onto other actors. In its own words, 'the Government wants to make progress without prescribing the use of specific technologies. Instead, information for market players, including households and businesses, should be improved' (DECC 2013: 79). Another reason, though, is expressed in the idea that current policy fills a 'big hole' inherited from previous governments. If the limited development of district heating can be attributed to energy policy having ignored heat, policymakers may feel an untapped potential exists which a 'small amount of help' can release. One civil servant explains how district heating has been adopted in policy:

> the strongest part of our story actually, and it's why ministers and others got interested in it in the first place, is that you don't have to believe that heat networks are the answer to all of our problems. You only have to accept that there may be some places where all of the factors add up together to make heat networks attractive and then we say 'why don't we just do them then'.
>
> *(Senior DECC policy officer, interview 2013)*

Thus rather than setting out to build large scale heat networks, policy is legitimated by an understanding that niche opportunities exist where 'all the factors add up'. These may be understood as forming the basis for larger systems in future or as generating better information about the costs and effects of district heating in the UK. However, reliance on niche opportunities runs a risk that small networks develop, as they did under the CEP, with high average costs, reducing both the cost-effectiveness of policy interventions and shaping understanding of the costs and performance of district heating in the UK. Ironically, then, this could make more ambitious heat network policies in future more difficult to adopt.

Notes

1 See www.heatandthecity.org.uk for more details (accessed 4 June 2015).
2 We are grateful to Ken Brady at the Energy Saving Trust Scotland for data on CEP grants.
3 Two of the authors, Hawkey and Webb, are members of the Extended Heat Network Partnership.

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PART III

Cities and urban centres: resources, expertise and sustainability challenges

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6

BUSINESS MODELS FOR DISTRICT HEATING NETWORKS

Economics, finance and risk

David Hawkey and Janette Webb

Introduction

This chapter discusses the variety of business models used by developers of district heating in the context of liberalised energy markets. It highlights the way that different business structures are made more, or less, feasible by regulatory and incentive frameworks, and their interaction with local objectives, as well as technical-economic factors such as availability of low cost heat sources, and density and diversity of demand. It focuses on business models used in places where district heating is currently very limited, as in the UK, and where energy market liberalisation has created a distinct break with earlier practices of public sector planning and coordination of systems for collective consumption (see Chapter 2).

The term 'business model' is polyvalent, resisting strict definition and amenable to various uses in theory and practice (George and Bock 2011). We do not adopt a strict definition of the term, but explore typical features of business models which illuminate the issues at stake in decisions about heat network development. These include costs and revenues, sharing of risk and responsibility across public and private sector actors, finance and judgements of investment viability. Given the range of goals which may be served, and their interactions with energy market conditions, there is no single universal template for district heating business models. What is viable is critically dependent on context: notably political decisions in relation to energy and climate change and associated regulations, the legacy of existing energy infrastructures and markets, and sources and costs of finance, as well as local leadership, climate and geography.

The cost structure of heat networks

Network infrastructure costs

The infrastructure costs of heat networks are often higher than equivalent gas or electricity infrastructure, due to the use of highly insulated pipework, and the width of trenches in which pipes are laid. Trench width is influenced both by pipework insulation and the fact that water is a relatively bulky transport medium. The cost of laying a given length of pipe depends on where it is laid – soft dig sites, such as under grass verges, are less expensive than installation under streets. In the UK, the poorly documented and sometimes haphazard location of other subterranean infrastructure can add costs, as the location of obstacles can be difficult to predict and manage (Green Building Council and Zero Carbon Hub 2010). Issues of cost unpredictability intersect with a lack of experience, resulting in civil engineering contractors applying high risk premiums. Overall civil engineering costs tend to be around twice the level they are in countries with established district heating sectors (Pöyry Energy and Faber Maunsell 2009).

Underground heat networks are regarded as sunk costs: once installed there is little or no financial value that can be recovered by digging up heat pipes and re-using them elsewhere. The operational lifetime of heat networks can be long (over 40 years), although business models tend to judge systems' viability on considerably shorter time periods of 15–20 years. The high cost of infrastructure means business models are often highly sensitive to the amount of heat that can be delivered through a given length of pipe, which is commonly analysed as being influenced by three factors (King and Shaw 2010). The first of these is concentration of heat demand in a given area: the higher the 'heat density', the less pipework is required for a given set of users. The second factor is the diversity of daily, weekly and seasonal demand patterns (demand diversity), which creates a more balanced aggregate load and increases utilisation of network capacity. This also improves cost efficiencies of heat supply into the network, by reducing the need for peaking plant and the frequency with which a heat source is switched on or off. The third factor is connection of large buildings with high and stable demand for heat to 'anchor' the initial economics of the network, around which smaller connections can then be made.

Figure 6.1 illustrates some of the spatial characteristics of heat demand in the UK. While the financial viability of heat networks depends on a wide range of factors discussed in this chapter, a commonly cited[1] threshold is $3MW/km^2$ (the vertical line in the figure). Taking heat demand across different sectors together, about half the UK's heat demand is in areas above this threshold (cf. UK Government's 2011 estimate in *The Carbon Plan*). Considering domestic demand separately (i.e. estimating heat demand density only on the basis of domestic heat demand), 16 per cent of heat demand is above the threshold; for non-domestic demand the figure is 13 per cent. While this is a rough calculation, limited by methodology and data quality,[2] it illustrates the extent to which different forms of heat demand are co-located in the UK, and shows the range of opportunities available above a given heat density for networks which combine different types of heat users. If domestic and non-domestic sectors are treated independently the total 'potential' for heat networks is around 30 per cent of demand, as compared with around 50 per cent if they are considered together.

As Figure 6.1 indicates, while the heat demand of non-domestic buildings is around two-fifths of the total, in areas of high heat density these buildings account

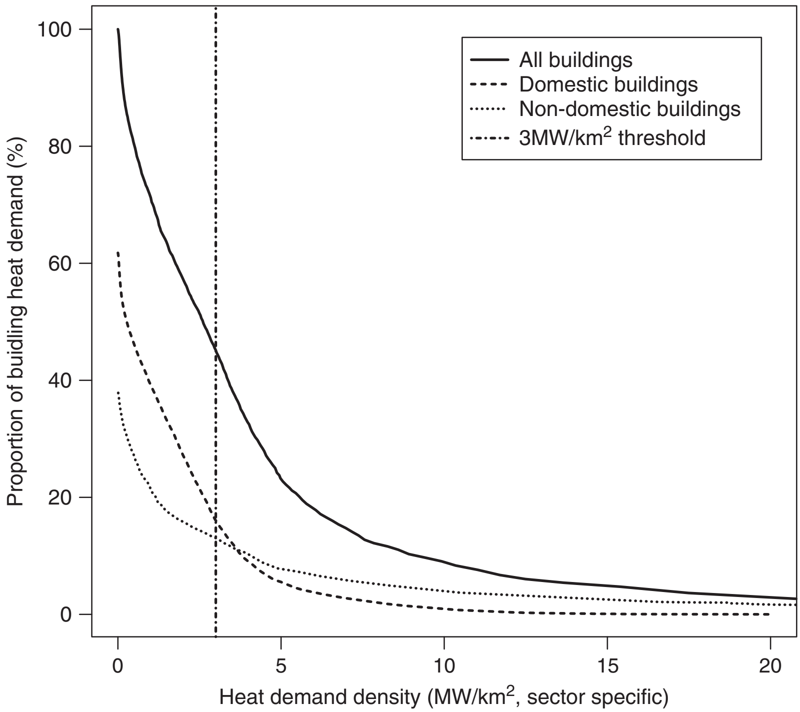

FIGURE 6.1 Proportion of heat demand located in zones at or above demand density (specified on the x-axis and calculated separately for aggregate, domestic and non-domestic building demand). Source: Based on 2011 gas and electricity consumption data for Middle Super Output Areas in England and Wales, and Intermediate Geography Zones in Scotland (DECC 2011).

for a more significant share of demand. Thus a development model which begins with highest density areas and moves outwards to lower density areas (as, for example, envisaged by the UK Department of Energy and Climate Change [DECC] 2013), would tend to focus on non-domestic buildings initially, incorporating domestic buildings later. This intersects with organisational and commercial issues (discussed below) to the extent that a business model tailored to non-domestic customers may be difficult to adapt to domestic supply later.

The role of anchor loads in district heating business models interacts with costs, revenues and risks. The large organisations which operate large buildings often represent lower revenue risks than smaller users, because of their likely financial position and their heat demand characteristics which tend to be stable. The additional cost of spare capacity in infrastructure serving a large heat user is relatively low. This enables easier extension to other smaller users, and is a common approach to growing a network and its user base (King and Shaw 2010). Anchor loads may also play a more active role in a network than simply being sites of demand. If heat supply is critical, for example at a hospital site, backup heat generators may be located there, affording benefits to the whole network while giving the anchor load first access.

The role of anchor loads in heat network development reflects a general characteristic of network infrastructure, which is that marginal costs (e.g. the cost of adding another user) tend to be lower than average costs (Helm 2010). For heat networks, a larger user base tends to correspond to lower infrastructure costs per unit of heat delivered, and also has other advantages. Larger networks are less dependent on the behaviour of individual users. They can integrate larger scale heat sources, meaning some sources such as deep geothermal wells or large power stations, which would be regarded as uneconomic for a small heat load can be exploited. Large heat networks taking heat from multiple sources require less backup per unit of heat delivered, because simultaneous failure of several primary sources is much less likely than failure of an individual source.

Large heat networks may reach the scale of a whole city. Such area-wide large infrastructure projects are typically constructed over a considerable period and may extend to hundreds of kilometres of heat pipes connecting multiple heat generators, and supplying upwards of 100,000 customers. Aggregate capital costs are high, but the network has the potential for steady cash flow from a large diverse user base. The city of Copenhagen Heat Network, with 98 per cent of households connected, for example, has a transmission system, which takes heat from multiple public and private suppliers according to best price, and supplies heat to local distribution networks.

Such large scale, planned systems may be built out from medium scale multi-site mixed user schemes, with diverse ownership of buildings, patterns of heat use and loads. Energy is likely to be generated and distributed via a number of inter-connected systems. The involvement of multiple parties creates a relatively complex project management process. This scale of development might typically support up to 20,000 homes, public buildings and commercial customers and cost up to £100 million. Few schemes of this scale exist in the UK, although the London Olympic Park and Stratford City project is a recent example of the model (Greater London Authority [GLA] 2013). The Olympic Development Authority signed a 40 year concession contract with private sector energy utility Cofely to design, build and operate an 18km heat and cooling network. At present the development serves the Olympic park and shopping centre, but the intention is that it will connect new housing and businesses to be built on the site in future.

In the UK, single-site projects are the most common, usually structured around a single stakeholder able to make the decision to connect the buildings which form the user base. Heat is supplied from a shared source to a given group of buildings; this could be a hospital site, university campus, public facilities or housing estate. The energy plant and network may be owned and operated by the heat user, or may be owned by, or leased to, a private energy utility under a long-term contract to supply heating, hot water, and possibly electricity and cooling. Project capital costs tend to be less than £15 million. The Wyndford Estate regeneration project in Glasgow, Scotland, is a typical example of a single-site private-public leasehold business model for district heating, albeit unusually large for a social housing retrofit in the UK (see Chapter 9). While development of smaller networks represents a less challenging coordination problem, their costs relative to their carbon and energy impacts tend to be higher than larger systems (see Chapter 5; Danish Energy Regulatory Authority 2014; UK Government 2006).

Small networks may over time grow into larger ones, for example by extension or interconnection. However, this requires 'future proofing' early design by ensuring sufficient capacity within the network to meet future heat load. Future proofing tends to add cost to schemes, but is usually less costly than, for example, replacing a length of pipe with one of greater capacity. Where the prospects for networks to expand to serve additional load are uncertain, as they often are in the UK, project sponsors and developers may have difficulty justifying the additional, speculative expense. In the absence of a planned approach to network development across an area, then, small networks may be designed in ways that make expansion into larger systems difficult.

Costs of supplying heat to heat networks

High costs of heat network infrastructure are often mitigated by low costs of the heat sources they are able to use. This characterises Scandinavian heat networks developed between the end of the Second World War and the 1970s oil crises. Cheap heavy oil burned centrally to supply heat via network infrastructure could undercut more expensive light oil burned in individual buildings (Chapter 3; Ericson 2009). Where climate change mitigation or renewable energy exploitation are prioritised this simple relationship becomes more complicated, particularly where government policies offer incentives for innovation and learning to reduce costs in the longer term. The relationship between costs of heat generating equipment and fuel sources adds a further dimension: high cost equipment, such as waste incinerators, generating heat from low cost fuel may be suitable for continuous (base load) heat generation, while lower cost plant using higher cost fuel may be more suited to intermittent heat generation to cover peaks in demand.

Combined heat and power (CHP) generators have historically been linked to development of district heating in the UK (Russell 1993) and Denmark (Chittum and Østergaard 2014), although less so in Sweden (Ericson 2009). Allocation of CHP costs to the respective heat and electricity outputs is a matter of accounting conventions, of which there are several (the Department for Environment, Food and Rural Affairs [Defra] and DECC (2012), list three methods, for example). Differences in conventions can lead to large differences in apparent heat cost, with the fuel cost allocated to heat varying by a factor of over four in different government calculations.[3] As heat and electricity are 'joint products' standard economic theory does not identify a unique convention, and different approaches are used in different schemes (and sometimes for different purposes).[4] Within a business model, then, the representation of cost associated with generating heat from CHP depends on the selection of an accounting convention, which in turn interacts with the formula for the valuation of CHP electricity (see below). This can have consequences both for how cost savings are understood (their attribution to saving on heating or power costs), and can significantly influence decisions on technology deployment and investment (Orchard 2013).

The costs of supplying heat to a heat network are not exhausted by the technologies and fuels required, because heat generation also has to be located somewhere. This is typically within a dedicated energy centre, for which land must be found. For a small scheme the options for energy centre location tend to be limited to the area of the network, because of the costs of pipework. For larger networks, heat sources can be located on a city's periphery where land values tend to be lower.

Heat network revenues

User payments for heat supply

Heat supply tariffs fall into two broad groups: cost-reflective tariffs, and market-based tariffs. The former tariffs share costs across users according to a formula, usually, though not always, taking into account the amount of heat each has used. Market-based tariffs structure charges in relation to the prevailing tariffs for alternative means of heating, which in many European cities is likely to be gas-fired boilers.

When heat networks adopt cost-reflective pricing, and infrastructure costs have to be recovered from heat sales, standing charges tend to be a relatively large component of users' bills. This reflects the relationship between high capital costs of infrastructure and low heat input costs incurred by the operator. In Denmark, for example, where cost-reflective pricing is required by law, high fixed charges for district heating interact negatively with policies targeting the thermal efficiency of buildings. District heating users have little financial incentive to adopt energy conservation measures such as additional building insulation, because the impact on their heating bills would be marginal (Chittum and Østergaard 2014).

Cost-reflective tariffs tend to insulate the heat network business model from the risk that revenues will be insufficient to cover costs. Users bear the risk that costs will be higher than alternative means of heating. With market-based tariffs the heat network owner bears this risk, and some regulatory regimes (for example, in Norway and the Netherlands) specifically cap heat charges at equivalent costs for alternative technologies. Conversely, however, if prevailing energy prices rise, the returns made by a district heating enterprise will grow too, and may be perceived as excessive, particularly if the heat network uses fuel sources such as waste incineration whose costs are not transparently related to competing heat prices. The switch from cost-reflective to market-based tariffs has led to controversial price rises in Swedish district heating schemes (Ericson 2009; Rutherford 2008). In the Netherlands regulators require district heating companies to report accounts for heat supply separately from other activities, seeking to detect excessive returns from market-based pricing (Autoriteit Consument & Markt 2014).

Some users may also be considered to have higher value for the developer, and hence may be offered a more advantageous tariff. As noted above, large anchor loads tend to represent low risk, and the building owner may be willing to enter long-term supply contracts. Alternatively, domestic users may be targeted, particularly if the objective of a business model is to alleviate fuel poverty, and if subsidies are available for initiatives serving this customer base. Domestic users tend to be regarded as higher risks in relation to non-payment of bills and variation in demand. Emphasis on consumer rights to switch supplier in liberalised markets may also make it difficult to lock households into long-term agreements. This can contribute to the difficulties of extending the user base of a heat network: commercial developers using a business model structured around sale of heat to large, low risk customers, will regard network extension to domestic users as financially unattractive.

The costs avoided by district heating users

Building owners are typically expected to derive a number of cost advantages from district heating connection. A heat exchanger which transfers heat from the shared network to a building's internal heating system, for example, usually requires less maintenance than a gas boiler. A component of the heat charges levied on users may hence reflect costs of alternative heating systems which they are assumed to avoid. Alternatively, such avoided costs may be used by the developer to justify a requirement for large organisations to contribute part of the capital costs of the district heating infrastructure. Avoided costs can be a source of contention, with differing opinions as to their relevance, scale and frequency. For example, a household may disagree with a heat supplier's judgement about the frequency with which a hypothetical gas boiler would break down and about costs of maintenance and repair, resulting in dispute over whether the heat charges represent a saving against a gas alternative.

Electricity revenues

Electricity from CHP can contribute revenues via a number of routes. Large generators may be able to participate in wholesale markets, but in the UK where heat network development is commonly based on megawatt scale CHP systems the costs and risks of wholesale electricity markets are prohibitive. Instead generators may sell electricity via a licenced supplier (a consolidator) at a discount on wholesale prices (Toke and Fragaki 2008). Higher value can be achieved by direct sale to users (or self-supply), because electricity can then be priced against retail prices. Direct sale tends to require a direct connection, bypassing the public electricity network, though the UK regulator Ofgem has developed a mechanism by which small generators can partner with licensed suppliers to sell power over the public network (Ofgem 2015). More complex revenue streams from CHP generation are also possible, such as offering Short Term Operating Reserve (STOR) services to the national grid through an aggregator. In this case, generators contract to respond quickly to imbalances in the public system.

The scale of revenues from electricity sales is sensitive to these different supply mechanisms, but such revenues may nevertheless be higher than those derived from the co-generated heat. This tends to result in business models which prioritise the production of electricity over heat. Small CHP engines usually produce heat and power in a fixed ratio, and so may be judged economical to run during periods when heat demand is less than heat output, because of the income from electricity. Heat network operators with heat storage may use this heat later, but other operators may resort to heat dumping.

Large CHP generators have greater flexibility in heat and power output, but in the UK tend nonetheless to focus on electricity production. For example, in 2010 Forth Energy, a partnership between an energy utility and a commercial port operator, proposed a series of four large biomass CHP stations in Scotland, three of which had illustrative electrical output capacities three times their heat output capacities. The emphasis on electricity production in these cases stemmed from a combination of relative perceived risk in heat and electricity sales. In current market structures, selling electricity via existing networks is less risky, and electricity achieves a higher sale price. In addition, the company calculated that the balance between government incentives to generate heat (the Renewable Heat Incentive) and incentives to generate electricity (the Renewables Obligation) skewed the project further towards the latter. Similar considerations tend to result in UK energy from waste plants emphasising electricity:

> The one thing I'll say with these plants is they could produce more electricity and less heat, they could produce more heat and less electricity but as things stand at the moment the money is in the electricity. So they'll tend to produce as much electricity as they can, as little heat as they can.
>
> *(UK local authority municipal waste officer describing commercial proposals for a local energy from waste plant, 2013)*

In Sweden where heat networks are well established, comparable CHP generators prioritise heat over electricity outputs (Forth Energy 2010), indicating the responsiveness of system operators to the regulatory and market framework which governs the balance of revenues from heat and electricity.

Judging the viability of heat network business propositions

The viability of a business model, that is the extent to which its costs are justified by its benefits, may be judged in various ways, depending on which costs and benefits are represented. From a social perspective, benefits such as reduced pollution or improved health, which do not translate directly into financial returns, may be considered relevant. A conventional financial analysis of viability would ignore such 'externalities'.

The cost comparator used in assessing viability of district heating tends to be 'business as usual', which is frequently gas supply in European cities. In the context of ambitious climate change policy and emissions targets, a more appropriate cost comparator may, however, be other *low carbon* heat technologies. Herein lies a tension between a business perspective, focused on financial performance of a stand-alone heat network, and a social perspective in which any particular energy initiative is one component in a broader, though uncertain, reconfiguration of the whole system. The difference is significant: consultancy analysis conducted for the UK DECC in 2009 concluded that heat networks were unviable commercially in most UK locations, when compared with existing gas grids and central heating systems. In the scenarios, the highest proportion of heat supplied by district heating was 0.3 per cent (Pöyry Energy and Faber Maunsel 2009). When the consultants instead compared the costs of carbon abatement using different low carbon technologies, heat networks were found to be more cost effective in dense urban areas than individual building solutions, the most competitive of which was heat pumps. While the specific features of this analysis should be read in the light of the variability and uncertainty in scenario modelling discussed in Chapter 4, the comparison illustrates the significance of the framing and definition of costs and benefits and the selection of baseline comparators.

Where heat from industry or CHP is used, the boundary determining which costs and benefits are included in judgements of viability may also be set in contrasting ways. One approach is to include the costs and benefits of heat supply along with all the other costs and benefits of the enterprise in an integrated assessment. Alternatively, the costs and benefits of heat supply may be judged separately, posing a more stringent test of viability. The latter approach is recommended by the UK Environment Agency (2014) for use in cost benefit analysis of heat off-take from large thermal-input sites such as power stations. Using this approach, a heat supply scheme would be judged viable *only* if the additional revenues from using the heat outweigh the additional costs of infrastructure and any other costs imposed on the 'core' business activities. Such an analysis is less likely to conclude that heat off-take is economically viable than an assessment of heat supply as a component of the whole system. For example a power station operator may calculate that supplying heat affords a lower overall return than operating in electricity-only mode (i.e. the additional costs are greater than the additional revenues), but that nonetheless this return is sufficient to meet its viability criteria. Regulators can also act to increase energy efficiency standards to a level which requires heat off-take, hence changing the formula for calculation of viability. This was a crucial component of heat network development in the Norwegian case discussed in Chapter 3.

The time dimension – discount rates

As heat networks have lifespans of over 40 years, the comparison of costs and benefits, or revenues, over time is a critical dimension of business models. In general, the simplest investment approach to time is to ignore it, instead focusing on minimising upfront costs without regard for on-going costs. For example, in high-rise social housing where a landlord is responsible for the heating equipment, but tenants pay the energy bills, the low upfront capital cost of electric storage heaters may be financially attractive to the landlord, despite the relatively high running costs for tenants.

A slightly less crude treatment of time is to consider the period over which the accumulated benefits of an initiative outweigh its costs. This is known as the payback period and is often a relevant criterion for organisations with limited capital and a reluctance to take on long-term debt. Shorter payback in financial terms allows capital to be recycled for other projects. Short payback can, however, be difficult to achieve with heat networks, where annual benefits are often small relative to upfront costs. Large systems may require several years of development, exacerbating this issue.

More sophisticated analyses use time discounting to calculate equivalence between costs and benefits occurring at different times. Time discounting can be used to judge either the financial return generated by investment, which is a crucial factor in commercial investment decisions, or the net benefit to society expressed in social terms as conceived by economic theory (Pearce *et al.* 2006). The approach draws equivalence between costs and benefits/revenues occurring at different times by scaling future impacts downwards by a factor analogous to compound interest. The outcome of this calculation is determined by the 'discount rate' adopted: a higher discount rate places less value on costs and benefits in the future, and corresponds to higher financial returns within a business model. For social analyses the UK Treasury (2013) recommends a discount rate of 3.5 per cent per year; estimates of commercial discount rates applied to heat networks vary from a minimum of 10 per cent to as high as 20 per cent (Homes and Communities Agency 2011). The impact of different discount rates increases with the period over which assessment is made, such that small changes can be hugely significant for long-term initiatives. For example, Defra (2007) estimated the potential for community heating with CHP, and found that reducing the discount rate from 9 per cent to 6 per cent increased its estimate of potential heat delivery by a factor of more than two hundred. The growing emphasis on commercial finance for heat networks in UK Government policy (see Chapter 5) tends however to increase the discount rate used in project assessments, with the likely consequence that fewer will be judged 'viable'.

The time dimension – synchronising infrastructure and users

Heat network construction and recruitment of users may take place over several years. The Norwegian DH system in Bergen, discussed in Chapter 3, was in operation for ten years before producing a cash surplus. Such a time lag between investment and returns can be challenging, depending *inter alia* on the requirements imposed by finance providers. The longer the period between investment in construction and the materialisation of heat demand, the larger this gap, and the poorer the overall returns from the system will be: deferred revenues are both more heavily discounted in business models and make up a shorter period of an envisaged asset life time. A study commissioned by Scottish Government (AEA 2011) into the use of residual heat from large power stations, for example, found city-scale systems would be viable at discount rates of up to 13 per cent per year if the entire assumed user base could be connected at once. A more gradual build up of demand over 15 years was found to reduce returns to below 3 per cent per year.[5] The viability of heat networks, therefore, is crucially dependent on the capacity of local actors to coordinate user connections to a system.

Business structures and risk allocation

Heat network schemes in the UK can in practice be broadly divided into those established to meet the goals of heat users (or their landlords), and those established to comply with building or planning regulations (see Chapter 5). The distinction reflects a difference in project sponsor. In the former case project sponsors are typically in the public sector, and are usually seeking to achieve a combination of affordable heating, local economic regeneration and energy/carbon saving. In the latter case, project sponsors are usually private sector developers seeking to comply with obligations imposed as a condition of planning permission. In both cases projects develop through the interaction between public and private sector organisations. The business structure adopted articulates the respective roles and responsibilities of different organisations, and shapes the location of risk and control, and the financing of initiatives.

Public sector project sponsors in the UK generally do not have in-house the range of capacities required to carry a scheme through detailed engineering design and construction on to operation and maintenance. There are various ways in which these capacities can be brought into a project, from contracting out different parts of the work to bundling the whole project into a business opportunity for a commercial contractor. Different approaches have consequences for the risks which the sponsoring organisation and its partners are exposed to, and the control they have over the evolution of an initiative. Transfer of control and risk away from the project sponsor may be deemed to be desirable, because it protects the financial position of the sponsor, and creates stronger incentives for a contractor to minimise costs and maximise efficiencies. Conversely, the less control a sponsoring organisation has, the less scope it has to change a project after a contract has been agreed with a commercial partner (United Nations Economic Commission for Europe 2008).

The relationship between public and private sector organisations in a business structure is mediated by European regulations designed to prevent public bodies from undermining market competition. Public sector procurement must be conducted through open competitive tenders, restricting the capacity of public sector bodies to make generalised commitments to particular suppliers. Long-term contractual relationships can be made compliant with procurement rules, but that relationship will then be constrained by the content of the original tender. The significance of rules about the use of public finance, which are intended to prevent 'State Aid' from undermining competition, varies from project to project. For example, in cases where a social landlord uses its budget to support connection of its tenants to a heat network, perhaps justifying this on the basis of avoided future costs of heating maintenance, it may have to make separate arrangements for the connection of any privately owned properties, even when they are in the same building (King and Shaw 2010). These competition rules tend to contribute to the fragmented pattern of district heating development in the UK, because they tend to reduce the flexibility of businesses to respond to changed circumstances, particularly the extension from an initial user base to other kinds of user (see Chapter 7).

The categories of risk typically associated with heat network developments (Pöyry Energy and Faber Maunsell 2009) are:

- Technology risk: innovative technologies such as large heat pumps or biomass gasification may fail to meet performance or cost expectations. Gas-fired CHP engines are commonly regarded as well established technology, and are common in UK district heating schemes.
- Construction risk, particularly budget or time overruns.
- Off-take risk, that is, the extent to which prospective heat users connect, purchase heat in predicted volumes, and stay connected.
- Operations and maintenance risks, which include ensuring that the system continues to deliver heat and compensates users in the event of any failure.
- Price risks: a business model often depends on financial projections based on assumptions about fuel input and heat (and possibly electricity) output prices. Gas-fired CHP is sometimes construed as having a 'natural hedge' as its input (gas) and output (heat and electricity) prices are expected to correlate in UK energy markets, due to the role of gas-fired generation in wholesale electricity markets.

Construction and operational risks are usually allocated to specialist contractors. Off-take risk is more difficult for a public sector sponsor to transfer to a commercial partner, because the partner is unlikely to be able to influence user demand. Responsibility for recruiting and maintaining the stable core of a user base tends to remain with the project sponsor. This may be enforced in various ways, for example if a local authority's own buildings use the network, it may agree to pay for a minimum amount of heat each year even if its actual demand is lower (so-called 'take-or-pay' contracts). Alternatively, a social landlord may agree to pay penalties to a commercial partner if any action by them subsequently reduces the volume of heat sold, such as demolishing a block of flats.

Where a developer responds to planning requirements by proposing the use of district heating, they tend to pass the capital costs of network infrastructure on to buyers, rather than seeking to recover them through long-term heat sales. This means that it is easier for planning authorities to enforce high standards of energy efficiency in buildings in places where land and property values are high, as in London, as the impact of heat network costs is proportionately low. While locking in users, and guaranteeing the level of heat demand, is not a characteristic of these schemes, local authorities are, nonetheless, important to ensuring a different form of market stability and security. The credibility of an authority's commitment to using local planning policies to support heat networks is an important factor in the viability of property developer-led projects, because it gives the developer confidence that the price of properties connected to district heating will not be undercut by competing developments subject to less stringent planning requirements.

Common business structures for heat networks

In the following section, common business models structured around the concept of an Energy Services Company (ESCo) are examined further, and brief case study examples provided.

Public sector lead using private sector contractors

A public body, such as a local authority, may decide to develop district heating as an in-house initiative or may structure the development by setting up a separate trading company. In both models, the sponsor retains a high degree of control and risk, and owns the revenues. Both approaches can be used to ensure that locally specified social, economic and environmental policies are embedded in business strategy. The user base, such as local authority buildings or social housing, tends to be within the control of the sponsoring body, thus mitigating off-take risks. If the sponsor decides to create a separate trading company, or ESCo, to manage the development, the new company will have no assets, and will struggle to raise capital at acceptable rates. It may however rely on the project sponsor to guarantee loans for design, construction and initial operation. Grant funding from other public sector bodies may also reduce the amount of loan finance required. Such contributions from public finance tend to result in use of a lower discount rate in assessments of viability, but usually mean that the scope of the initiative will be constrained by state aid rules.

The advantages to the public sector sponsor of creating a separate company derive from the direct focus which this brings to the business of district heating development, management and cash flows. Holding the business at arms-length may also afford a degree of protection from any fluctuations in the financial position of its sponsor, in the context of their broader strategies and responsibilities. A separate company can, for example, hold any surplus revenues in a sinking fund for future capital replacement. UK local authorities operating district heating in-house find this device difficult to justify, given their constrained budgets.

Using an independent business structure also creates the potential for subsequent refinancing by introducing third party capital. This is exemplified by Sheffield city council, which developed Sheffield Heat and Power in the 1980s, using heat recovered from waste incineration. The business was subsequently sold to the waste

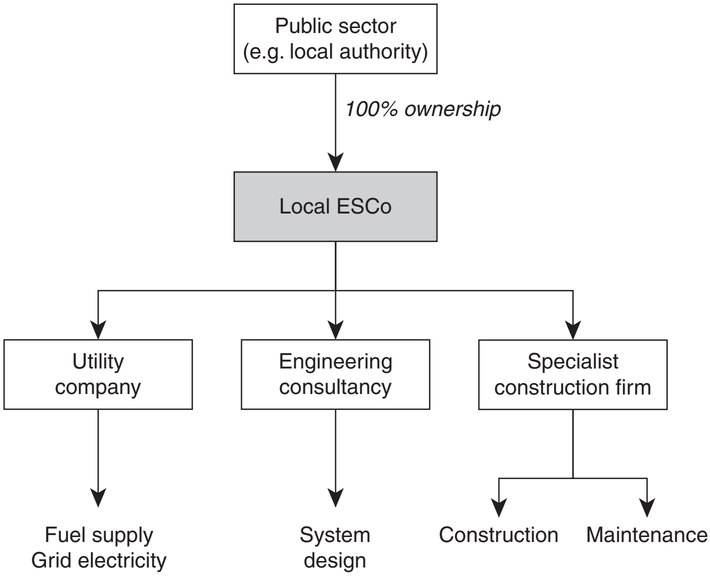

FIGURE 6.2 Schematic example of a district heating ESCo wholly owned by a public sector organisation (NB only an illustrative set of activities are shown, in practice there are typically more).

management operator. This transferred operational risks away from the council and released capital, but it also reduced the city authority's scope to direct subsequent development of the network.

Islington Borough Council and Bunhill Heat and Power: an in-house vehicle for heat network development

Bunhill Heat and Power was created by Islington Borough Council to develop a heat network for supply to an established social housing estate. The network has 1km of pipes, connecting 850 homes and 2 leisure centres to a gas-fired combined heat and power plant. The main aims were to alleviate fuel poverty and to reduce energy costs. There are plans to connect a further council-owned housing estate and to introduce additional local sources of waste heat from the London Underground and a nearby electricity substation (Islington Borough Council 2013). The initiative is managed within the council and capital costs were funded by grants from the Greater London Authority and the UK Government's Homes and Communities Agency. Two contracts were tendered: a design and build contract situated all construction risk with the contractor, for which the council paid a premium; and a ten year operation and maintenance contract was also let. Factors shaping the decision to retain the scheme within the local authority included the benefits of capacity building for council officers, retention of local control over decision-making, low projected financial returns which were considered unattractive to commercial parties, and funding deadlines which were incompatible with alternative solutions (Scottish Futures Trust 2015).

Aberdeen City Council and Aberdeen Heat and Power (AHP): an independent non-profit ESCo

Aberdeen City Council led the development of combined heat and power and district heating as a means to reduce fuel poverty, upgrade energy performance standards in housing and improve council revenues from housing stock. It created an independent non-profit company, limited by guarantee rather than shares. The company is required to work for the benefit of the citizens of Aberdeen, and the council is represented through membership of the company board, but is not in a majority. Aberdeen Heat and Power Ltd (AHP) has thus far worked under contract to deliver council-funded projects, using a legal provision which exempts the council from EU requirements that such contracts must be subject to competitive tender.[6] Grants from UK government, and a contribution from the council on the basis of avoided future costs have been significant to the initiative. Council decisions to underwrite the financial risks of the developments also enabled the company to borrow at rates close to those available to the public sector. This facility was important in allowing AHP to respond to changing conditions, particularly the need to extend its third network to a council leisure complex when a number of multi-storey housing blocks planned for connection were withdrawn due to the poor condition of the building fabric (see Chapter 7).

AHP has a small core staff, and contracts out technical design and project management, as well as legal and financial services. The company charges the council for heat supplied to tenants and the council in turn passes these costs on through its heat with rent scheme.[7] The company's exposure to potential non-payment by tenants is thus limited; other main heat users present low risk of non-payment, being predominantly in the public sector. Chapter 7 includes a fuller description of the Aberdeen heat networks and the challenges faced in extending from council-controlled users to commercial heat supply.

Joint venture, or hybrid, public-private energy service companies

In a joint venture or hybrid structure, ownership, control and risk are formally divided between public and private sectors according to negotiated equity shares or membership. The allocation of risks and rewards is governed by a series of, potentially complex, legal contracts defining responsibilities and customised to the objectives of the parties. Private sector partners bring expertise in energy markets and business, but the rate of return for private sector capital will be higher. Where a local authority is a party to the business, it may act as the investor in infrastructure, and potentially contribute land or other assets. Such structures appear relatively little used in the UK, despite periodic proposals. Joint or hybrid structures are more common in larger schemes in European cities: for example, the Dutch schemes discussed in Chapter 3 have structures of this type.

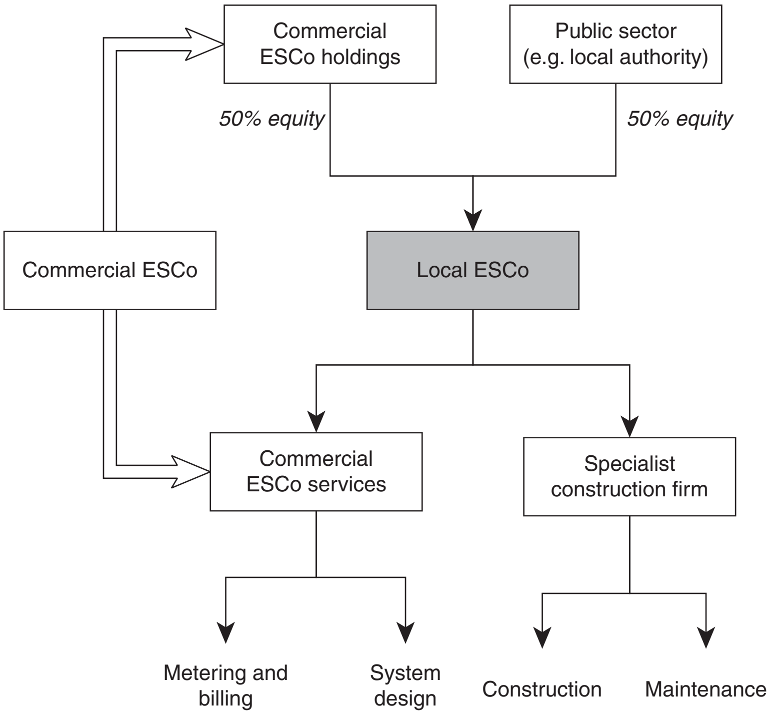

FIGURE 6.3 Schematic example of a district heating ESCo jointly owned by public and private sector organisations (NB only an illustrative set of activities are shown, in practice there are typically more).

Woking Borough Council (WBC) and Thameswey Energy Ltd

During the 1990s WBC developed a series of energy efficiency initiatives, including small scale CHP and heat networks. These were regarded as successful in both environmental and financial terms, and the council sought to scale up the approach (Energy Saving Trust 2001). In 1999, the council established a joint venture, Thameswey Energy Limited (TEL), with a Danish company. WBC took a 19 per cent equity stake in the business, which used grant funding from the UK Community Energy Programme and commercial debt to develop several heat networks with CHP. WBC's financial exposure was thereby limited to less than 4 per cent of total project costs. Had WBC taken a larger equity stake, rules governing local authority finances at the time would have required the company to be treated as part of WBC for accounting purposes (London Energy Partnership 2007).

The company's most significant CHP and district heating initiative in Woking is anchored by council buildings, but has been extended to several private sector residential and commercial subscribers. The scheme was sized to serve a housing development, which was subsequently cancelled, leaving the system with excess capacity. TEL has also developed a CHP/district heating scheme in Milton Keynes (about 100km away) serving new development on land owned by a public sector agency responsible for economic enterprise; the agency uses planning requirements to support development of the district heating system.

By 2005, changes in the accounting treatment of UK local authority companies and in Danish tax law had resulted in WBC increasing its shareholding in TEL to 90 per cent. TEL's articles of association prevent it from being entirely owned by the local authority. The company continues to use commercial debt for projects, which are refinanced after construction, using long-term debt provided by WBC at commercial rates. This increases the council's exposure to project costs, which are reported in its financial accounts, but also provides a revenue stream.

Private sector energy service company structures

In a private ESCo, the main project risks and revenues are located with a commercial developer, as is control over future strategy. The major advantages to a public sector sponsor of a private ESCo are risk transfer and the technical and commercial energy sector expertise brought to the business. The higher rate of return required by private finance however usually translates into a higher overall cost for services, and project sponsors have to provide long-term guaranteed heat revenues in order to secure investment of private finance. Private sector business models may also be supported by public sector contributions, for example in the form of land for an energy centre. Such guarantees and contributions support the credit quality of a project, enabling the private sector ESCo to secure loans at lower interest rates. The extended due diligence period entailed in negotiation of these structures lengthens the development timetable, but may also result in more rigorous evaluation of the business model. The drafting of the contract between project sponsor and contractor is critical to the degree of future control exercised over the direction of district heating operations and connections. Performance standards may be written into such contracts, but it may be difficult to pre-establish a long-term strategy for system development which correctly anticipates future circumstances and requirements: 'the risk with this approach is that the less certainty there is over the scope, and timing, of future phases the less clear it is that putting development into the hands of a single provider is prudent' (extract from engineering consultant report of technical-economic feasibility, and business models, for district heating at a development site in a UK city).

Extension of a network to additional users may be possible if the marginal costs and benefits satisfy the ESCo's financial requirements, but it is unlikely that a commercial ESCo will voluntarily cross-subsidise low-return network extensions from the higher, secure returns made on large anchor loads. There is, therefore, a risk that large heat users are 'cherry picked' rather than used as the foundation for a more extensive system.

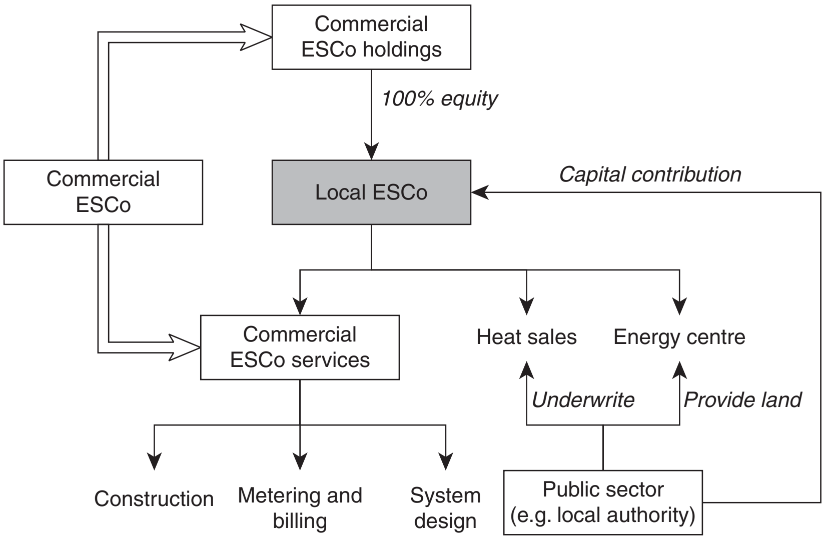

FIGURE 6.4 Schematic example of district heating ESCo wholly owned by a private sector organisation (NB only an illustrative set of activities are shown, in practice there are typically more).

Birmingham City Council and Birmingham District Energy Company Ltd (BDEC)

Birmingham City Council regarded CHP with district heating and cooling as an efficient, cost- and carbon-saving contributor to economic development strategy, but considered direct investment and system operation to pose unacceptable risks to council finances. The council tendered for a commercial utility to design, build, finance and operate the scheme. Utilicom[8] won the contract in 2006 and established Birmingham District Energy Company (BDEC) as a wholly owned subsidiary, thereby encapsulating project financial risk. The council, along with the University of Aston and the NHS children's hospital, entered 25 year contracts under which they guarantee to purchase energy at prices governed by market indices designed to ensure savings on the main alternative supply.

The city council thus has only indirect control over future investment strategy, and in effect entered an exclusive arrangement with the utility company for serial development of schemes. BDEC has established three CHP/district heating centres and networks (total CHP capacity 7.5MW_e). The first scheme has been extended to the city's new public library and to two multi-storey housing blocks. BDEC's parent company was unwilling to finance extension to social housing, which was funded instead by a grant from the UK Low Carbon Infrastructure Fund.

Devon County Council and E.ON: new build Cranbrook housing estate and Skypark developments

Regional and local authorities identified the city of Exeter as a priority site for new residential and commercial development, both to keep pace with anticipated local economic growth and to tackle local problems in housing affordability. An additional 18,500 homes are indicated for development across a range of sites by 2026 (Element Energy 2008). In order to be compliant with building regulations, the later phases of development at the large residential Cranbrook site necessitated the use of district heating. Financial viability however also required connection of the initial phases of housing and the connection of heat load from the adjacent commercial development site, Skypark (RegenSW 2011). Public ownership of the land at Skypark gave authorities greater influence over the commercial development partner. The proposed scheme was estimated at £24m capital investment, with £9m of this met from avoided costs of alternative energy infrastructure.

In 2009 the local authorities secured a UK government Low Carbon Infrastructure Fund grant (£4.1m) with a tight spending deadline of 2010. To avoid the delays and complexity of public procurement processes, it was agreed that the commercial developers would take responsibility for appointing an energy company to deliver and operate the scheme, and for negotiating costs to property developers, commitments to connect subsequent phases and heat tariffs (RegenSW 2011). E.ON was the company selected. The key risk of volume of heat sales is mitigated by local and national public sector policies supporting connection of successive phases of property development to the system. Other development and commercial risks are shared between E.ON and property developers.

Conclusions

The relatively high capital costs of heat network infrastructure mean that network configuration is both a crucial, and highly variable, dimension of district heating business models. The ratio of heat supply to sunk investment tends to be higher for schemes in areas of high heat density, supplying a mix of user groups. Heat network economics tend to mean that larger networks have lower average costs than smaller systems. Cost structures also shape prescriptions for network development trajectories; large heat loads serve to anchor systems with redundant capacity, enabling easier and more rapid extension of the network to further users.

Constructing a district heating business model is, however, more complex than simply laying cash flow over a technically optimised network configuration. Chapter 5 discussed the impact of policy fluctuation, grant funding deadlines and specific user-based objectives on the scale of heat networks developed in the UK, and Chapter 7 explores in more depth the difficulties encountered in coordinating multiple organisations around development of a heat network. These factors tend to make small systems more feasible than more ambitiously scaled networks. Problems are exacerbated by potentially lengthy procurement processes and the important role played by timing in the assessments of viability of business models.

The increasing diversity of ESCo business models demonstrates the increasingly subtle structuring and allocation of risks, as interest in district energy as a means to affordable warmth and carbon saving has developed. From a neo-liberal perspective this diversity in business models may be considered a mark of cross-sector innovation. However, it may also serve to lock in a fragmented pattern of district heating development. While small heat networks may be envisaged as part of larger future systems, this requires 'future proofing', which adds costs likely to be difficult for public sector or commercial organisations to justify, in the absence of effective mechanisms to establish a growing user base. To the extent that business structures are tailored to specific characteristics of an initial user base, small systems may also struggle to accommodate a broader range of users and additional heat sources. A commercial operator may for example be unwilling to invest in network extension beyond anchor loads. In addition, the scope for aggregating small schemes to a scale acceptable to institutional investors, whose required returns tend to be lower than other commercial investors (see Chapter 5), seems likely to be restricted.

While financial viability is a crucial concept in the contemporary construction of district heating business models, the framework for assessing such viability is not subject to universal or invariant rules. It can be assembled according to very different criteria, including the choice of comparator, or counterfactual scenario, the definition of relevant costs and benefits, and their distribution over what length of time. The balance between social and commercial objectives set by the assessment framework is particularly consequential. Higher required rates of profit increase the price of heat supply, particularly if the capital invested in infrastructure has to be recovered from revenues.

Judgements of heat network business viability are hence shaped by the regulatory context, which is governed by highly varied mechanisms. Regulation may focus on protecting user interests, through non-profit operating requirements, as in Denmark, or price-caps and customer protections of the kind adopted in Norway and the Netherlands. It may focus on protecting the developer's interests by securing a significant long-term user base through spatial planning and zoning for district heating and the use of high building standards. It may focus on maximising the efficiency standards for operation of large thermal installations including power generation. It may also govern the type of financing available and its costs, through market incentives and/or rules for the use of public funding and public procurement. Frequently used in some combination, these dimensions of regulation interact to frame the distributions of risk across stakeholders, limiting some possibilities and opening up others. In the UK context, the most significant regulatory issues are the weakness of mechanisms to secure a significant user base, which contributes to the fragmented character of heat network development, and the relatively low energy efficiency standards for thermal installations such as waste incineration, combined with use of cost-benefit formulae which provide little incentive to use the heat generated. In liberalised energy markets, where there is an established higher carbon heat alternative, the absence of a regulatory framework specific to new district heating infrastructure limits the scope for effective development and attainment of the scale and scope economies of the technology.

Notes

1 Pöyry Energy and Faber Maunsell (2009) introduced the 3MW/km^2 threshold on the basis of characteristics of the UK housing stock.

2 Issues include the way in which spatial zones for data reporting are defined, low resolution indications of the location of a lot of non-domestic heat demand (as a means to protect commercial confidentiality), inferences from gas and electricity consumption to heat demand, and the fact the analysis ignores relationships across spatial boundaries, instead treating all zones independently.

3 The simplest method allocates fuel to heat and power in fixed proportion (twice as much fuel allocated to electricity as to power). The more complex methods use a displacement approach. The power station displacement method allocates to electricity output the fuel that would have been used to generate the same quantity of electricity in a non-CHP power station, with the remaining input fuel allocated to heat. The boiler displacement method conversely allocates to heat the fuel that would be used in a heat-only boiler and the remainder to electricity. Clearly among these methodologies there is scope for variance in how counterfactuals are determined. For example, displaced power generation could be calculated as the marginal plant on the public network, the most efficient plant (either on the public network or technically feasible), or some reflection of anticipated changes in power generation, including increased use of renewable electricity. DECC's calculation of the relative allocations under different methods draws on generation data across a range of technologies and fuels, so the figure quoted here is actually a reflection of the average CO_2 emission factors calculated for heat under the different methods for 2010 data.

4 For example, the Danish Energy Agency assumes that the efficiency of heat generation by CHP is 120 per cent. That is, to calculate the fuel allocated to heat generation, they divide the heat output by 1.2; the remaining fuel is allocated to electricity generation (Danish Energy Agency 2014).

5 Though note that the analysis made the unrealistic assumption that all capital costs would be incurred in the first year, rather than incrementally as additional buildings were connected.

6 Under a 'Teckal exemption', where a company is largely controlled by one or more local authorities and carries out most of its activities with those authorities, the authority does not have to use public procurement routes when requiring further work.

7 Aberdeen City Council's 'Heat with Rent' scheme is not restricted to tenants connected to the heat network, but pools the costs of heating across a number of sites including homes with gas-fired boilers and electric heating.

8 Subsequently Cofely, following takeover by GDF Suez.

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7

URBAN ENERGY GOVERNANCE FOR SUSTAINABLE HEAT IN UK CITIES

Expectations, practices and potential

Janette Webb

Introduction

In Chapter 2, we discussed the restructuring of relationships between European states, markets and civil societies, with respect to the broad shift in political economy away from a Keynesian-style welfare capitalism advocating state-management of aggregate demand, to neo-liberal advocacy of extension of market principles across multiple societal domains in a low tax regime. A correspondingly 'lean' or 'minimal' state is formally oriented to progressive withdrawal from direct public provision of goods and services. These generic principles of neo-liberalism are taking context-specific and contingent forms in different states and localities, highlighting the indeterminacies inherent in any political-economic philosophy, and its perpetual openness to contest and alternative political projects. In the UK, privatisation and liberalisation of energy, and erosion of the powers and resources of city councils pose considerable challenges for governance of innovation in sustainable heat.

In this chapter we examine responses to those challenges through case studies of UK cities where carbon and energy saving strategies include plans for district heating and improved building insulation. We argue that the ensuing project developments need to be understood in relation to the UK variant of neo-liberal political economy, and its instruments of governance. Notably, we suggest that the increasing use of market commissioning by city governments for services and infrastructure, combined with declining budgets and lack of capacity in energy systems, is associated with incremental, rather than more coordinated systemic, change in heat provision. Capacities to draw third party heat sources into a system, or to coordinate a growing user base for district heating (see Chapter 3) are weak in the UK. The resulting small scale, project-focused and bounded developments also risk locking in technical constraints on system expansion, making it difficult to realise the economies of scale envisaged in technical scenarios for future urban sustainable heat systems (Chapter 6). The case studies reinforce one of the central arguments of the book that technical-economic models indicating the energy and carbon efficiency of combined heat and power (CHP) and district heating for cities are insufficient to drive systemic change. Instead the prevailing social, political and economic institutions are significant in explaining what is done in practice.

Case studies are used to explore the translation, and contestation, of neo-liberal logics in relation to local sustainable heat projects. This enables examination of the scope for local energy plans to gain traction with, or against, the grain of neo-liberal regulation and market mechanisms, or indeed in creative tension with such logics. It draws critical attention to the scope for local agency, using whatever capacities and resources are available, to effect material change in heating provision, in the context of increasingly globalised energy markets. Existing research suggests that local initiatives are likely to depend on the emergence of intermediaries, willing and able to work across boundaries between different sectors and domains of knowledge and expertise (Newman 2014). Areas of technical specialism and expertise, such as building services or urban design and engineering, which were once more closely aligned as part of local government, have been increasingly outsourced, creating greater need for intermediaries able to navigate the divisions between multiple parties in any building retrofit or CHP and district heating projects. Such actors are key to mobilising others around a common narrative of legitimate purpose in local, low carbon, energy developments. These actors are likely to be local politicians and officers with long-term responsibility for local welfare. They do not need to hold a formal intermediary role; instead their office, or political status, confers local powers and access to policy arenas, and their values and affective commitment to locality may give impetus to work and responsibilities beyond a potentially circumscribed remit.

Why case studies?

Case study methodology aims to reveal the situated logics of action in different localities where the distinctive mix of politics, social relations and resources can result in differential decisions and particular patterns of material change. Case studies guard against over-generalisation from grand narratives such as neo-liberalism; they challenge such conceptual closure by virtue of their ability to show the continuing diversity of practice (Flyvbjerg 2001). In relation to sustainable heating, case studies provide insight into the complexities of institutional disruption and socio-technical change. The examples used here explore the reasons for development of low carbon heat in particular settings, the different business and governance arrangements established, and why plans may stall or be subject to multiple revisions and uncertainties. The material translation of neo-liberal policies and instruments into local practices of economy, social relations and resource use is highlighted. The aim is to reveal the practices and rationalities of power and resistance, and their material expression in control over energy resources and welfare. In this sense, such case studies also provide a route to critical analysis of UK low carbon policies, and their fitness for purpose at urban scale.

The uncertain trajectory of sustainable heat projects in UK cities

Case studies from four different cities are used to examine contrasting patterns of local governance for innovation in sustainable heat, the reasons why plans are developed with different priorities, and the resulting material consequences for localised heat supply. We compare two cases where development has proceeded successfully, albeit on a limited scale, and contrast these with brief accounts of two cases where development has stalled, or is taking a more fragmented form from that initially envisaged. This allows us to reveal common structural constraints, and the scope for certain forms of local agency with different logics, outcomes and trajectories. We identify by name the cities where district heating developments have proceeded, because these are publically known exemplars. We anonymise the other two cities, because these are on-going unresolved projects with a degree of sensitivity over eventual outcomes.

The material used in the analysis was collected between 2011 and 2014, and combines observation and participant observation of project meetings and related events, with documentary analysis and semi-structured interviews. The latter were mainly audio-recorded and transcribed in anonymised form. Interviews followed a partly biographical format, and a partly problem-oriented format seeking insight into processes of actor formation in relation to specific heat network projects. We also draw on four one-day knowledge exchange workshops[1] convened as a component of the research, and attended by UK urban authorities actively developing local energy provision. In this chapter we rely primarily on a subset of the data: first the transcripts of 33 interviews with officers of city governments, and government agencies, health service and university estate managers, representatives of district energy companies, engineering consultancies and financial services representatives; second the documented plans for, and evaluations of, sustainable heat developments, as well as maps and feasibility reports where available, and third fieldwork notes from meetings observed.

Urban combined heat and power and district heating developments in Aberdeen and Birmingham

During the first decade of the twenty-first century, a small number of district heating projects were established on the basis of local initiative, aided by capital contributions from the UK Government 2002–2007 Community Energy Programme (CEP) (discussed in Chapter 5). Councils in Aberdeen,[2] a small city in North East Scotland, and Birmingham[3] a large English city in the West Midlands, were among those receiving funds for combined heat and power and district heating developments. Both cities have been subject to post-industrial decline and reconstruction, and have significant populations with low incomes. Aberdeen has a long history in merchant shipping, food processing and fishing industries, but is now known as a major service centre for North Sea oil and gas. Birmingham was a pioneer of the industrial revolution, but manufacturing industry has declined radically since the 1980s, leaving a commercial, retail and public service-based economy. Both cities now promote themselves as entrepreneurial actors in global competition for financial investment for a future low carbon economy. In Aberdeen for example emphasis is placed on a future city-region hydrogen economy, which is presented as a route to secure prosperity as the oil and gas industry declines. In Birmingham, the concept of a 'growth coalition' of council, business leaders and state interests has encompassed aspirational planning for low carbon energy services as one means to re-build the city's historical reputation for innovation.

In both cities, local energy provision is presented in strategy as a means to improve economic resilience, and its interpretive flexibility is evident in the different priorities pursued. Aberdeen council positioned CHP and district heating primarily as a means to improve the welfare of low income households, while Birmingham council regarded the same technology primarily as a means to city centre economic regeneration. The respective projects emerged out of different specialist divisions of the city councils, and their different goals proved consequential for decisions about governance and business structures, heat tariffs and the main types of customers connected to district heating. In both cases, further development has continued beyond the end of the CEP, with on-going investment in infrastructure managed under contrasting contractual structures. Overall both systems remain small by European standards, but are, in the UK context, significant and distinctive, offering two contrasting exemplars of potential routes forward for other cities.

Aberdeen City Council and the Formation of Aberdeen Heat and Power Ltd: the Community ESCo Model

In Aberdeen, district heating development originated with the city council housing team, culminating in 2003 in the establishment of local non-profit community Energy Services Company (ESCo), Aberdeen Heat and Power Ltd (AHP). The primary purpose of the business is to work for the benefit of citizens through provision of affordable low carbon energy for heating. The council does not have majority control of the AHP board of directors, with only two seats reserved for elected members. Governance is based on a 50-year legal agreement,[4] where council specifies the development, and AHP installs, operates and maintains the systems. AHP must in turn comply with European regulations for competitive procurement, and hence acts through an agency relationship with the city council. Three gas-fired CHP energy centres (total CHP capacity 2.6 MW_e) have been developed at Stockethill, Hazlehead and Seaton, with a fourth under construction at Tillydrone. The systems supply heating and hot water to 33 of the city's 59 multi-storey housing blocks, as well as a school and 12 further public buildings. Some of the co-generated electricity is supplied via private wire to the school and other council buildings; the remainder is sold into the public network. In 2012 a Scottish Government grant enabled the extension of the heat main to the city centre, and additional multi-storey housing blocks are planned for connection during 2015.

Prior to establishment of AHP, council initiatives had focused largely on improving standards in low rise housing. Energy efficiency in the city's electrically heated multi-storey housing was very poor, and 70 per cent of tenants were assessed as living in fuel poverty. The UK 1995 Home Energy Conservation Act (HECA) served as a catalyst to more ambitious action. The Act required local authorities to identify measures for a reduction of 30 per cent in home energy consumption and associated carbon emissions between 1997 and 2007. Local responses varied, but anti-poverty politics in Aberdeen resulted in a decision to create an energy conservation office within housing services. The appointment of an officer with community development, rather than housing engineering, expertise, cemented a commitment to systematic community engagement and an open-ended appraisal of options. This provided the local intermediary identified in other research (Newman 2014) as critical to local public service innovation in a neo-liberal context.

The resulting Affordable Warmth strategy prioritised the reduction of fuel poverty through low cost heating for tenants, and served as a foundation for alliance building across council specialisms. A 2002 revision notably integrated new commitments to carbon reduction with welfare goals. A technical-economic appraisal of options recommended replacement of electric storage heating with CHP and district heating for clusters of multi-storey housing. It was also suggested that creation of a community non-profit ESCo, rather than use of a commercial contractor, would assist in meeting council commitments to low heat tariffs. This was a politically contentious proposal, however; the council lacked direct experience of such energy systems and supply chains, and the economics of CHP and district heating, with high upfront investment cost, were regarded as difficult to reconcile with local government duties to apply principles of 'best value' in procurement. These principles require local authorities to secure continuous improvement in their operations, with regard to economy, efficiency and effectiveness. Although this does not equate to lowest upfront cost, the pressures on council budgets mean that short-term cost principles are frequently dominant. As noted in Chapter 6, in high-rise social housing such as that in Aberdeen, the low capital cost of replacement electric storage heaters is financially attractive to the council, despite relatively high running costs for tenants. The key to challenging this perspective was the Affordable Warmth Strategy, which had embedded 'cost in use' to tenants as the criteria for council decisions, rather than short-term cost of heating equipment to council. Cost in use, based on time-discounted cash flow, was the metric against which options had been assessed, but acceptance of the resulting recommendation of a significant change in heating systems would require the council to capitalise future housing budgets to finance the upfront construction costs. Despite Scotland-wide and local anti-poverty political strategy, and carbon management plans, the proposal to invest in CHP and district heating was a source of significant internal council dissent.

The legitimacy, costs and risks of district energy, in comparison with its claimed benefits, were contested between and within housing, planning and finance. The finance team were concerned not only about the potential implications for council borrowing, but were also wary of the proposal to set a flat rate, affordable, price for heat to be collected with rent, because of the risks of non-payment by tenants. The council's legal team advised against proceeding, because of the financial risks. Loan underwriting and the likely need for prudential borrowing to capitalise AHP on the basis of anticipated future savings from the housing revenue budget, were particular matters of concern. Political mobilisation by the energy conservation officer nevertheless gave momentum to the proposal, which was subsequently considered by the full council committee. The deputy leader, a Labour councillor, chaired the meeting:

> At the founding meeting he said 'we are obliged to seek the advice of the council's solicitor, but we are not obliged to take it. Therefore it is noted.' So he put it to one side. So he had the political courage.
>
> *(member of AHP Board and district energy practitioner)*

A key factor in overcoming the doubts of local politicians and officers seems likely to have been the fortuitous availability of a capital contribution under the UK CEP. The council's housing committee indicated in principle willingness to use capital for CHP and district heating for clusters of multi-storey housing, but set a maximum cost per household equal to the new gas central heating systems installed in low rise housing. This typically left a 40 per cent gap in budgets, but capital funding from the CEP enabled the shortfall to be overcome. The initial project was selected for its relative simplicity, connecting four multi-storey housing blocks to a new energy centre, with heating from a gas-fired CHP engine, and back-up gas boiler, and was evaluated as successful by council and tenants.

Increased council confidence in CHP and district heating and in the viability of the community ESCo model enabled two further applications for CEP funding.[5] The second and third CHP/district heating systems achieved higher efficiencies by connecting more diverse heat loads to the network. Use of private wires for local electricity supply to some buildings further improved their financial performance. The third development provided a route to subsequent expansion and additional finance. The CEP funding was based on projected carbon saving from connection of 11 multi-storey housing blocks. Poor fabric condition of a number of blocks resulted in their unplanned withdrawal, risking loss of the grant. A council leisure complex was selected as an alternative means of achieving the target carbon savings, but with additional cost, which had to be managed by a relatively inexperienced AHP board. An overdraft facility, underwritten by Council, was eventually used to resolve the short-term cash flow crisis, and provided impetus for greater strategic responsibility to be taken by the AHP Board. The development proved critical for subsequent network extension into the city centre, funded by an ad hoc capital grant from Scottish Government, with further connections to National Health Service (NHS) and council facilities. The oversizing of pipework, initially unplanned but managed through a degree of improvisation, thus enabled interconnection of island systems and increasing economies of scale in the use of the assets.

Aberdeen council became a lead recipient of funding under the UK CEP, with three awards totalling £2.6m[6] out of a total £7.7m investment. Part of the explanation for capacity building in Aberdeen seems attributable to its role in UK multi-level government politics, and the decision by a Scottish Labour-Liberal Democrat coalition to fund a cross-sector community energy network to facilitate funding applications: 60 per cent of the CEP grant funding went to Scottish projects (Department for Environment, Food and Rural Affairs 2008). Since the end of the CEP in 2007, subsequent UK and Scottish Government grant funds have been smaller, and again time-limited. The council has however continued to work with AHP in extending provision. A second CHP engine has been installed at the Seaton energy centre and work has proceeded on three further clusters of multi-storey housing. In each of these cases, council officers have negotiated grant finance of circa 40 per cent of capital costs under successive energy company obligations to provide energy efficiency improvements for low income households. Carbon saving is estimated to be 40 per cent, in comparison with former electric heating systems in multi-storey blocks and replacements for central heating boilers in public buildings. Heat tariffs for tenants have been maintained at an affordable rate (currently an estimated saving of 50 per cent on equivalent electric heating). The National Home Energy Efficiency Rating (NHER) of the housing blocks with improved insulation and connected to the heat network was reported by council as improved from 3.3/10 in 1999 to 7.19/10 in 2009. AHP has now established a for-profit subsidiary, District Energy Aberdeen Ltd (DEAL), opening up business opportunities to connect commercial heat loads and to supply electricity via private wire. This structure enables any profits to be returned to AHP to maintain low heat tariffs for social housing tenants and to contribute to network extension. Longer-term aims include replacing gas CHP with technologies such as energy from waste, biofuel boilers, hydrogen cells, large scale heat pumps and thermal stores for geothermal sources.

Birmingham City Council and the Formation of Birmingham District Energy Company Ltd: the Commercial ESCo Model

In Birmingham, district energy was positioned as a component of a low carbon economy, and led by urban design and engineering. As in Aberdeen, the welfare politics of fuel poverty stimulated a 1980s pilot CHP and district heating scheme, but subsequent project development in 2006 was governed by the city's Conservative-Liberal Democrat 'growth coalition' priorities and placed reliance on market commissioning with the aim of minimising capital investment by the council. The city council tendered for a private contractor for the supply of gas-fired combined heat, cooling and power to large scale public and commercial users, resulting in a 25-year private-public partnership with district energy business Utilicom. The Birmingham District Energy Company (BDEC) was established as a for-profit subsidiary of Utilicom, a firm subsequently acquired by GDF-Suez and restructured as energy services company, Cofely. BDEC directors are employees of Cofely; a partnership board gives a profit share to large subscribers, which is taken in the form of a rebate on energy bills. The long-term contract guarantees revenues to Cofely from sales of heat, cooling and power. The commercial tariff is set at a rate competitive with equivalent market tariffs for gas central heating and electric cooling for large users. Large campus-based users (university, hospital and council facilities) also gain a competitive price for power. The council and other major heat users in the city centre negotiate network extensions and connections with Cofely, but the revenues generated from committed users must satisfy the commercial returns on finance required by the company. The company has limited capacity to make strategic investment on the basis of anticipated demand, and surpluses accrue to international shareholders.

Birmingham's urban design engineers already had working knowledge of CHP and district heating and were the key advocates of its potential as an economic efficiency measure when city centre regeneration plans were developed at the start of the twenty-first century. As in Aberdeen, proposals to localise energy supply were contentious, but a key difference from Aberdeen proved to be the unwillingness of the council to borrow, thus requiring mobilisation of private finance. In this case, the engineers proposed the replacement of gas-fired boilers in city centre facilities with CHP and heat and cooling networks. The lead proponent faced opposition on a variety of grounds, including the short-term cost, doubts about reliability, concerns about potential exploitation associated with long-term commitment to a single supplier and unwillingness of council to borrow in order to finance such infrastructure. He sought to counter the objections using a number of strategies. First he aimed to mobilise political support by linking the attributed efficiencies and sustainability of CHP and district heating technology with local Liberal Democrat manifesto commitments to *sustainable* growth. The Liberal Democrat deputy council leader proved to be a critical 'political champion', becoming an intermediary in subsequent negotiation within council and among potential partners. Second the design engineers identified the business model described above by reference to a similar model, involving the same district energy company, in Southampton. They believed this would be acceptable to local politicians averse to public borrowing. A site visit to Southampton by Birmingham politicians and officers encouraged further investigation of the technical-economic feasibility of a similar approach in Birmingham city centre. The private ESCo model aligned with council commitment to market commissioning, and the subsequent development prioritised a commercial approach. This focused on large buildings, predominantly controlled by the city council (council offices, a convention centre, sports arena and leisure and retail centre). Additional users include a hotel built by the city council, but operated by an international company, and a repertory theatre. The status of these buildings as nationally significant facilities meant they posed limited commercial risk. This contrasts with the domestic, fuel poor user base relied on in Aberdeen.

With short-term cost competitiveness defining value, the third aspect of intermediary work by city engineers sought to constitute CHP and district heating as a long-term cost-saving measure in economic regeneration strategy, and again the potential for an element of CEP funding provided an incentive. CEP applicants were required to use a time-discounting approach, described by the lead engineer as 'Whole Life Costing' (WLC), to demonstrate the viability of any proposed development. In principle such techniques are expected to be useful in defending the value of higher initial costs in relation to measured long-term benefits. The validity and reliability of WLC accounting techniques were however subject to a degree of council scepticism. Nevertheless the WLC framework was advocated by the engineers as a route to improved financial control over life cycle costs of energy provisions, including unplanned engineering problems, plant breakdown and uncertain future energy prices. This strategy enlisted tentative support from council finance specialists. Such risks, it was argued by engineers, could be priced, and allocated to a private partner, with the aim of securing local competitive advantage. Assembling the cost calculus for energy services in whole life format, using component costs of network connection, future energy price forecasts for heat, cooling and power supplies, and maintenance and repair, plus avoided costs of alternative equipment, proved sufficient to frame a cost-based rationale for consideration of a long-term private sector contract for district energy.

The legal issues surrounding technical specification and procurement were described by engineers however as a 'can of worms' and the council legal team were regarded as risk averse and lacking in the requisite experience. Internal negotiations proved complex, with disagreement over the cost formula, the financial and technical credibility of bidders, the relevance of EU state aid rules, and the risks that promised competitive energy prices would prove unreliable under a long-term monopoly contract. The project team needed time to feel comfortable that they understood all of the issues, but they had to conclude an agreement within the CEP deadline. Eventually a last minute bid was made for a CEP financial contribution to project costs. The application received a grant of £700,000 towards a total project cost budgeted at £1.86m, and BDEC was created.

The private ESCo model formally externalises project risks of system development, operation and retail supply (Chapter 6). Conversely control over the heat network assets lies with the contractor, creating an obstacle to extending access to other heat suppliers, who may be able to supply heat at a lower price in future. Future strategy has to be governed instead through on-going legal contractual negotiation, usually with a highly experienced counter-party, which of course has its own costs. In Birmingham, the district energy procurement specification was subsequently regarded as too tightly drawn, making it harder to expand the system and to build interconnections between 'island' networks. Three schemes (total CHP capacity 7.5 MW_e) have nevertheless been established. The second and third schemes supply a university, a hospital, magistrates' court and additional council buildings, and are close to a regeneration area which may provide future customers. In its most recent developments, the council and Cofely have negotiated network extension across the city centre to connect the redeveloped New Street Railway Station and a major retailer.

In the longer term, the city's *Climate Change Strategy and Action Plan 2010* sets out the aspiration for energy self-sufficiency. Like Aberdeen, a city-wide heat network is depicted as a critical component of the vision. Secondary schools are envisaged as hubs for a neighbourhood network of biomass boilers, using council estate 'waste' wood and the old industrial infrastructure of the canal network for low impact transport, alongside investment in energy from waste. Advancing such a plan requires considerable reduction in energy use for the built environment. Since the old industrial cities like Birmingham are intensively developed, the means of retrofitting buildings is critical. Market commissioning continues to be the main mechanism for this, as evidenced in a further joint venture between the city council and transnational construction corporation Carillion.

The contrast between the social ESCo and commercial ESCo models exemplified in AHP and BDEC centres on the resulting distribution of costs and benefits. In Birmingham, plans for social benefits from low carbon energy, notably connecting 20 per cent of social housing to district heating by 2020, are challenging, given that the commercial ESCo structure relies on revenues from a small number of large users in order to meet the required investment return. There is no obligation on a private supplier to find means of financing system extension to connect low income households, where capital costs are high relative to financial returns and debt risks. In this case, the connection of two Birmingham city centre multi-storey housing blocks instead relied on further UK government funding for low carbon infrastructure, with work managed directly by the council. Conversely it is difficult for AHP to operate a commercial model, because its legal structure deliberately protects the interests of tenants in affordable heat supply. It is too early to know the future trajectory of its commercial subsidiary, DEAL, although it has recently received loan funding from Scottish Government to increase its capacity with the intention to supply heat and hot water to private sector student accommodation, although the intention is that any surplus revenues would be used to protect low prices for social housing tenants.

Coordinating heat network development under uncertainty: where projects stall

With hindsight, the end of the CEP marked a further shift in the political-economic context for UK heat network developments. The main emphasis has since been on commercially viable business propositions and private finance, with incentive payments for energy from renewable sources largely displacing government grants. Remaining grant funding is located with energy companies, under the government obligations to address fuel poverty. The approach is exemplified, as discussed in Chapter 5, in the structure and powers of the UK GIB and Scottish REIF, which are designed (in accordance with the efficient markets hypothesis) to avoid undercutting private investment, and to act as a stimulant to *market development*. Two assertions follow; first that 'market barriers' or 'failures' are preventing development of energy efficiency markets for technologies such as CHP and heat or cooling networks, and second that these are amenable to dismantling by government regulatory mechanisms and incentives on the one hand, and strategic investment on commercial terms to adjust the prevailing financial calculus on the other. Finance for carbon saving technologies then needs to be structured predominantly around equity and debt, either through market commissioning by large heat users who can effectively guarantee long-term returns on investment, or through direct ownership by one or more parties, with a contractual structure to govern new supply relationships. Such finance situates heat networks as bounded projects, with the boundary being a financially reliable user base.

Two case studies are briefly discussed below to show user responses to the prevailing circumstances of market commissioning and finance models applied to plans for new heat network developments. In both cases, the technical-economic feasibility, and energy and carbon savings, of proposals for shared heat supply are accepted in principle by the main parties, but in practice each is constrained by their organisational cost-benefit frameworks in ways which tend to undermine the logic of long-term collaboration. Despite the presence of intermediaries in each case, the coordinated formation of a viable project has thus far stalled.

East City

In 2006, just before the global financial crash, a significant green field site in East City had been identified as a target for high profile science park development. A major NHS teaching hospital, developed under a 1998 Private Finance Initiative (PFI) contract, and university clinical research facilities were already on site. A second NHS hospital was in planning, and the university was committed to further development of clinical research facilities. The city council is both the relevant planning authority and owner of land and housing adjacent to the site. Before the financial crash, government had envisaged a private finance-led development, and had recruited a private sector joint venture partner:

> We have an American partner who creates life science parks throughout the world, or did until the market downturn … from 2006, we went into a partnership with them. We would have been looking for a pre-let from … one of the large pharma companies, and speculatively building a building for them.
>
> *(government enterprise officer, East City case)*

Since the crash, the private developer 'very much took a back seat' (government enterprise officer), and the enterprise agency instead used public funds to build serviced office and lab facilities.

The decision to develop the site was contentious, because of its green field location, creating pressure to ensure protection of the environment and the highest standards for energy and resource efficiency. In contrast with city centre retrofit, it was also expected that the green field site meant relatively straightforward integration of sustainable infrastructure into all development. Planning guidance included stringent requirements for CO_2 emissions, with a target reduction of 50per cent more than minimum building standards. An early options appraisal had identified site-wide district heating as a key factor in meeting the target. At the time of our research, a more detailed technical, economic and legal feasibility analysis of district heating had also reported that carbon targets could be met along with a financial return of 15 per cent per year from revenues over 25 years.

Throughout this period, a central government enterprise and business development agency worked as intermediary, meeting jointly and separately with the other public sector parties over a period of years, to mobilise shared commitment to a globally prestigious demonstration site for low carbon, hi-tech economy. In 2014 discussions about shared energy supply from a heat network were however unresolved. The business incubator facilities had gone ahead with standard energy provisions; both the new hospital project team and university estate managers were exploring CHP schemes serving their own facilities. All of these decisions served to weaken the economic and carbon reduction case for shared site-wide provision. Future plans drawing in other heat users, such as social housing, beyond site boundaries were also being discussed.

West City

In contrast with the East City green field proposal, this project was intended largely as a retrofit of district heating. The involvement of parties was again voluntary, though the project was framed by a city-wide sustainability initiative ('West City Future', or WCF), which aims to meet ambitious sustainability targets through cross-sector partnerships. The WCF partnership, which was catalysed by one of the city's universities, identified district heating as central to city-wide energy and climate goals, and the project discussed here was one of a handful of opportunities being considered. Being the most centrally located, it was known as the West City Centre Cluster (WCCC). Participants paralleled those involved in the East City case: the NHS, two universities, a further education college and the city council. In addition partner organisations of WCF, including one of the UK's major utilities, were represented. As in East City, a government agency, this time with responsibility for carbon management, acted as intermediary in seeking to broker agreement between parties to coordinated development.

During 2012, the parties met to consider the report of a detailed technical-economic feasibility study, which estimated that a heat network would achieve almost five times the carbon reduction suggested by an earlier analysis (16.6 kt CO_2 per year), and payback a year and a half faster (8 years vs 9.5), but with an immediate requirement for twice the capital (£14m). The estimated internal rate of return (13 per cent per year) was described as 'commercially attractive' and twice that shown by the previous study.

In 2014 discussions were on-going. With the exception of the city council, all of the public sector organisations in the WCCC had explored onsite CHP schemes and were at various stages of development. These undermined the area-wide configuration presented in 2012. Studies of technical-economic potential of a multi-organisation system, drawing in other heat users including social housing, and conducted by a different consultancy, were however still being discussed.

Accounting for limited progress in heat network development in East and West cities

In the UK political-economic and energy market context, the means of coordination among multiple parties to new heat network infrastructure is elusive. There is no immediate need, legal compulsion or market advantage. A mains gas grid and regulated market for fossil fuel gas serves urban buildings, whose owners typically assume responsibility for installing a stand-alone heating system. Voluntarism hence characterises any coordinated investigation of shared infrastructure development to explore any likely advantages:

> There's no need for us to really interact with [university], and even less with [housing association]. … somebody has to bind all those people together, and you have to bind them together … first of all you have to force them to work together, and once you give them a common purpose, I think it will work, but it won't work naturally.
>
> *(West City university estates manager)*

> Even down at [East City science park site], you know, you just despair. … you can't even have a sensible discussion about integration because it is all your different stakeholders, different contracts. Unless you're legislated it ain't going anywhere.
>
> *(East City university estates manager)*

In both cases, in principle commitment of all public sector parties to explore options was secured through a government intermediary seeking to broker the formation of a shared project. The main tools available to each intermediary centred on the technical-economic feasibility study, which was used to show the carbon and cost saving potential of district heating, either at the time of renovation (in West City), or new build (in East City). The feasibility studies centred however on a non-existent 'problem owner' or economic actor who would receive the commercially attractive return on investment gained from some form of joint enterprise between organisations. This proved to be a weak instrument to govern collaboration, with technical-economic measures of costs and benefits contested by the parties, who pulled in different directions.

The commercial framing of proposed heat network developments

In both cases, the background assumption was that development would be a commercial proposition, commanding relatively high rates of return:

> we were looking at it very much from cost reduction perspective. You know, looking at how to sell that, and also just in terms of even, you know, institutional investors.
>
> *(Government Enterprise Officer, East City case)*

> Someone pulled out a map of West City and saw [commercial building] fills up four blocks and thought 'phoar, we'll have them'.
>
> *(West City commercial building manager)*

The technical-economic feasibility studies used standard discounted cash-flow analyses to establish the attractiveness of the proposition to finance providers, and suggested three possible ESCo structures: privately owned, publically owned or a public/private joint venture. Heat users would engage with this entity as retail customers, although they may also have had a stake in ESCo ownership under a public or joint venture model. The perspectives of participants however varied considerably and the model was not necessarily accepted as working to their advantage. In both cases, coordinated development was perceived to carry the risk to their organisation of 'subsidising' benefits to others, while gaining too little on their own behalf. The advantage to each separate organisation of a stand-alone system conversely undermined the efficiencies of a shared scheme: while interconnection may be technically feasible it is much less clear how its costs are going to be covered:

> The NHS have their system and we have our system here and there's [x] million pounds worth of interconnection work that needs to happen in between them, who is going to pay for that? That's an interesting question.
>
> *(West City university carbon and energy manager)*

In West City the consultants' report also envisaged all users paying the same rate for heat supply. Participants questioned whether their involvement was subsidising others. In part the difficulty stemmed from the fact that different organisations were currently on different energy tariffs. The hospital, whose effective heating tariff was calculated as lowest, was presented with *zero* heating bill savings. The hospital would instead save on electricity bills, whereas the other participants would not take electricity from the scheme. The estimated value of this saving was roughly equivalent to the heat bill savings projected for one of the universities, but the latter's heat demand was two-thirds less than that of the hospital. GHG emissions' savings, via CRC carbon charges, were also translated into financial savings for the hospital, but these savings were regarded as weak in relation to other costs. The consultants suggested for example locating the ESCo energy centre on the hospital site, but this implied additional costs of building demolition and use of land with potentially high value.

The commercial frame hence created a perspective where each party considered the perceived commercial advantage or disadvantage to their own organisation, to whom they are directly responsible. Carbon was no more than 'a helpful bonus' (West City university estates manager) in the actual rationality at work. In each city this resulted in the main parties (though not the councils) reconsidering the value of their heat and electricity use, and appraisal of options to invest in CHP and district heating systems for their own facilities. This removed the risks of delay and the transaction costs of negotiation and multi-party contracting, and 'protected' what became defined as a valuable user asset (rather than liability) in the form of high heat load. These actions stimulating single user CHP and district heating development in turn create the potential asset of heat supply for export to others, and simultaneously create a new base line for calculation of what constitutes best value. Whereas the initial feasibility study situated a communal system as financeable from savings made against gas boilers, future proposals would have to undercut onsite CHP systems, resulting in reduced revenues to cover the costs of shared infrastructure.

Public procurement and the disciplining power of 'best value' measures

It was not necessarily the absolute price of heat supply for any user which was critical in militating against coordinated action. The potential reputational price of being seen to deviate from a standard practice was also a consideration, with business-as-usual conferring shelter from anticipated media criticism:

> [A freedom of information request could reveal] you were paying x before, now you're paying x+10, who thought that was a good idea? Then your name's all over the papers about squandering.
>
> *(West City university estates manager)*

> At the end of the day, if the press gets hold of it, the press just tears these things to shreds and blows them out of proportion.
>
> *(West City NHS estates manager)*

The best value imperative was hence interpreted as a relative measure whose dimensions were informally conditioned by a media hostile to public spending. Parties in West City preferred to stay with an existing public sector procurement club for gas and electricity, even though tariffs offered to different organisations under this arrangement varied. The reverse counterfactual, that costs within the procurement club would exceed those of a communal system, was not an evident cause for concern. Deviation from the procurement club would mean perceived inefficiency would be blamed on the organisations (or even the facilities managers) themselves. Within the procurement club, the club itself would be the site of responsibility for achieving 'best value'. This was not because a comparative techno-economic analysis demonstrated this, but because the 'best value' problem could be passed from the individual organisation to the club, where it would be answered by theories grounded in dominant ideas about competitive markets.

This structural conservatism was an important issue contributing to hesitancy among parties, but it did not override other concerns. In both cities, public sector participants recognised that failure to contribute to greenhouse gas abatement and low carbon economy would carry cost, both in terms of non-financial values and goals in health and higher education sectors, and in terms of political costs of failing to support local and central government aspirations. The disciplining power of 'best value' and related performance measures in this sense is also encountered through organisational and sectoral, rather than area-based, commitments. This meant that each party proceeded to examine ways in which their own organisation could meet carbon saving objectives independently. Notably each hospital and university considered autonomous development of a CHP system, which was generally deemed to be a lower cost measure than a coordinated system, and creating less risk of reputational damage, even though area-wide carbon savings would be lower in the immediate future. In West City the trend to autonomous action was reinforced by low carbon grants becoming available from the higher education funding body. Such grants are organised by sector:

> Because [the grant funder] is giving the cash to ourselves it needs to be ring fenced around, [they] can't be giving us money to enable somebody else.
>
> *(West City University carbon and energy manager)*

In addition the short-term deadlines set by such public bodies were incompatible with the longer period required for a coordinated solution. Decisions on investment by these organisations were hence not conditioned by local relationships, but by the narrow windows of opportunity set by sector authorities. Funding for carbon reduction in the higher education sector became available because of perceived limited progress on sustainable energy in universities and colleges. The opportunity for West City universities to mobilise finance was hence conditioned by the national sector, not their relationships with geographical neighbours, and not the economic rationales embedded in either the consultants' report or the West City Future vision of financially and technically integrated systems development. Scope for *local* coordination is thus highly constrained: the units that would be combined under the imagined communal system are only partially local; their actions are simultaneously and more potently embedded in national and international sectoral processes. Each party proceeded to pursue its own variant of 'best value', beginning with appraisal of options for developing separate CHP systems. Although each sought to ensure technical potential for subsequent integration, this route effectively undermined the financial model for a collaborative system.

The impact of private finance on decisions about collaborative heat network development

The hospital estates in each city were critical to anchoring the envisaged carbon saving and economic benefits of a shared heat network. In East City, both existing and new hospitals were subject to the disciplines of the Private Finance Initiative (PFI), a UK-wide scheme to draw private investment into the construction and operation of public infrastructure, including schools, prisons and hospitals. The difficulties are illustrated in relation to the existing hospital developed with its own CHP and district heating system in the late 1990s under a 30-year PFI contract. During the subsequent inter-party discussions about a shared heat supply system for the whole of the East City green field site, it was suggested the existing hospital could make efficiency gains by supplying its surplus CHP heat to an area network. The Special Purpose Vehicle (SPV) created to design, build and operate the hospital is owned by a consortium of businesses and financial institutions. The complex legal structure of the multi-party contract resulted in any proposed variation being perceived as introducing new cost-bearing risks. A proposal to create a new business interface, where heat from the hospital CHP would be supplied to another network, was thus considered a business risk:

> effectively the whole [SPV for the existing hospital] are the operators. It's 12 banks that are financing it, and for any decision to be taken all 12 banks need to agree … So [SPV] have told us before and told the NHS that they do not wish to see any change in their risk profile and any change in their profit, because that will cause the banks major headaches, because they obviously … they're buying into an income stream.
>
> *(Government Enterprise Officer, East City)*

The NHS body considered the inflexibility to be frustrating, and counter to its duties of sustainable health service provisions, but nevertheless felt unable to act. Along with the BDEC example above, this suggests that the complex structures of long-term procurement contracts introduce new forms of rigidity which may serve as obstacles to public sector low carbon energy strategies.

Discussions about site-wide provision of district heating in East City with the second planned NHS hospital as a critical anchor load also proved unproductive, despite a government intermediary offering incentives in the form of a small increase in land available for the hospital estate. The project board responsible for commissioning the new hospital considered the technical-economic model recommendations, but decided not to include a requirement for district heating connection in the competitive tender, arguing that uncertain timing of any joint network infrastructure, combined with legal issues around the relationship between the hospital contractor (who would be expected to take the availability risk of heat supply[7]) and a heat supplier would add unnecessary risks, jeopardising the development timetable. The level of detail, and hence workload and stress, entailed in specifying terms of a long-term commercial contract for complex facilities and services, and the perceived human and economic costs of any subsequent variation in terms made locally responsive collaboration unlikely. PFI contractual instruments thus worked to limit local control over alternative options for a coordinated solution to sustainable heat supply.

East and West Cities – summary

In both cities, the case for development of a low carbon heat supply in a defined area through collaboration between public sector organisations, government and potentially private parties relied on the modelled efficiencies and carbon savings in technical-economic feasibility analyses. Public intermediaries worked to build common commitment to sustainable energy provisions through innovation at local scale, using the feasibility study as a vehicle for generating consent through identification of communal carbon saving. Each analysis focused on the heat loads contributed by local organisations, but calculated returns to a non-existent economic actor and did not translate these into a case where each party perceived benefits to their own organisation. This proved ineffectual, because it focused on the wrong 'economic actor' – each party was assumed to be willing to contribute their heat load to the whole, while an envisaged system developer would retail heat at a competitive price consistent with a commercial return on investment. Each study also noted the potential advantages from scaling up the envisaged project to city scale, but structured its envisaged financing around a bounded case for the single cluster of users.

The organisations presented with the feasibility analysis perceived the risks and demands of such voluntary collaborative development as high, and had no structural obligation to work together in the locality. Indeed the performance frameworks in which they are obliged to operate are sectoral and national rather than local, reducing any likely cooperation across public sector budgetary 'silos'. The assumed commercial framing for such projects was also associated with a degree of suspicion that one organisation might be subsidising benefits accruing to others. This perspective was reinforced by the 'best value' framework, which is delineated by organisational boundaries, as well as reputational risk in the face of a perceived hostile media, and PFI/PPP instruments which militate against flexibility in discovery of locally coherent carbon and cost savings. Instead each party reverts to a calculus of single-organisation costs and benefits, simultaneously weakening the case for over-arching sustainability gains. The 'missing link' in each case is arguably the city council. Although city officers were party to discussions, the councils proved unwilling at the time to use such capacities and powers as they had to take a lead role in formation of the necessary economic actor through for example the institution of a local ESCo.

Implications for developing urban-scale sustainable heat in the UK

The work of developing urban heat networks in the UK's neo-liberal political economy is shown here to rely significantly on the emergence of local intermediaries able and willing to assemble available capacities and intermittent funding opportunities. Mobilisation through intermediaries proved to be a necessary, but not sufficient, factor to effect material change in urban heat provision. Hence the presence of intermediaries in East and West cities did not result in the formation of an economic actor with the competence and material resources to develop district heating. Collaboration between multiple complex parties, with sectoral rather than local accountability, made for at best halting progress. In addition the standard evaluation of feasibility is governed by a bounded financial definition of a stand-alone heat source and network serving a specified cluster of buildings. This commercial project model risks the creation of island systems, which are difficult to interconnect, and which are therefore unlikely to achieve the envisaged sustainability credentials of urban scale heat networks.

In Aberdeen and Birmingham, intermediaries forged alliances geared to exploiting the opportunities of the UK CEP, which worked to reduce the perceived risks of district heating projects. The instruments of liberalised political economy also proved tractable to different local objectives and governance structures. Community ownership and social welfare was prioritised in Aberdeen and commercial ownership and economic advantage in Birmingham. The differentiation of urban policy and practices in UK multi-level government is frequently overlooked, but is shown here to create different potentialities for action, leading to material difference in provisions and contrasting models for ownership and shares of costs and benefits from district heating.

These developments remain relatively small scale, however, as in other instances of UK district heating. A key factor which accounts for this is the current UK variant of neo-liberal governance. Relative to European comparators with liberalised structures of energy governance (discussed in Chapter 3), current regulatory, competition and public procurement practices interact to reduce the scope for local and regional coordination between energy utilities, city councils and other private and public sector organisations. The result is weaker foundations for the attributed carbon and cost efficiencies of heat network provisions at urban scale. 'Tight coupling' of public infrastructure development and market mechanisms has powerful disciplining effects on organisational decision makers in relation to interpretations of 'best value' and risk. The terms of private-public contracting were also seen to act as a constraint on local collaboration between organisations, introducing forms of inflexibility into decision-making about district energy networks. This makes the type of investment in 'passive provision' currently sought by UK Treasury (2015), and suited to insurance for future carbon targets, very difficult to justify at any stage of investment. Collaboration across organisational and sectoral boundaries is correspondingly rendered high risk and is marginalised, resulting in limited momentum for systemic, area-wide decarbonisation of heat. Instead, projects tend to tailor development of a heat network to the limited user bases which can be coordinated. Consequently, UK heat networks face significant hurdles to extension across the different market, public and community strata of a city.

Notes

1 Workshop discussions were conducted under the Chatham House Rule.
2 Aberdeen's population is approximately 220,000.
3 Birmingham's population is approximately one million.
4 This is governed by a *Teckal* exemption which provides that, in certain circumstances, the award of a contract by one public body to another separate legal person will not fall within the definition of 'public contract', with the result that EU law will not require the contract to be put out to tender. The exemption comprises both a 'control test' and a 'function test'. (1) The local authority must exercise similar control over the contractor to that which it exercises over its own departments, and (2) the contractor must carry out the essential part of its activities with the controlling local authority or authorities.
5 The three CEP grants received by Aberdeen city council were for £660,000, £610,000 and £1,330,000.
6 Aberdeen Council received 9 per cent of capital grants made by the UK CEP.
7 The availability risk of district heating is arguably unknown in the UK, so organisations tend to make a worst-case assumption.

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8

ASSESSING LOCAL GOVERNMENT ENGAGEMENT IN ENERGY SYSTEMS DEVELOPMENT IN THE UK AND ITS LIKELY TRAJECTORIES

Margaret Tingey, David Hawkey and Janette Webb

Introduction

Chapters 6 and 7 explored the development of district heating business models and local governance initiatives, using case studies of activity in particular places. Here we shift focus to consider local energy projects across the four countries of the UK, asking to what extent and where energy initiatives are under development, and what role heat plays within those initiatives. We find considerable diversity across the UK in the technologies and business models employed at a local level, and explore tension between flexibility and fragmentation this diversity reflects. We also discuss the role of national, devolved and regional levels of government in shaping local sustainable energy activity alongside characteristics of local authorities and local areas that correlate with levels of local government engagement.

We treat local authority areas as our unit of analysis because visions of local authority engagement with sustainable energy have a long history of promotion by both central and local governments (as discussed in Chapter 1). There is also a practical reason: relevant data is organised by local authority administrative areas. We present results from a population survey of local authority areas with which we interrogate the extent to which patterns of engagement in sustainable energy have developed over the decade or so since the identification of a 'second wave' of local authority activity (Bulkeley 2010). We also present three brief case studies which illustrate the themes that emerge from the survey.

The context for contemporary local engagement with energy in the UK

In this section we discuss some of the characteristics of local government in the UK, and findings from other research, to introduce the themes we explore with our data set in subsequent sections.

Compared to other European states, UK local government is subject to a high degree of centralised control (see Chapter 2). Historically, the legal *ultra vires* principle has been used to prohibit local authorities from undertaking activities not explicitly permitted by central government statute (Slack and Côté 2014; Wilson and Game 2011). In principle a greater degree of local discretion has been in place since the early 2000s, due to the introduction of 'well-being' powers, and the lifting of certain forms of central government control over local authority spending decisions.[1] The reforms allow local authorities to engage in any activity which they judge to improve local social and economic well-being. They do not however release local authorities from statutory responsibilities for core services, or confer greater control over local taxation; in the UK central government determines around two-thirds of aggregate local authority budgets (Department for Communities and Local Government 2014a) and both UK and Scottish governments have sought to freeze the tax rates over which local authorities nominally have discretion ('Council tax'). The non-statutory nature of UK local authority engagement with energy also means that initiatives are likely to be reliant on opportunities associated with statutory duties such as waste management, housing and local transport. Such initiatives are marginal to the priorities of the core service specialism (Bulkeley 2010), and hence vulnerable to disruption in the face of evolving priorities and constraints. Consequently, Betsill and Bulkeley (2007: 450) found that energy and climate policy 'often remains fragmented at the local scale'. A planned, strategic and purposive approach to low carbon energy is challenging in this context, because local authority actors have to be willing to develop opportunities which are contingent on statutory responsibilities. In addition, they to have find resources from the gap between the costs of statutory responsibilities and fixed total budgets. This suggests that larger authorities should have more scope to find and maintain some budget to support capacity building by, for example, employing in-house specialists. In addition, the larger estates of these authorities may afford more opportunities.

Local authority structures vary across the UK, and since 1998, local government matters have been devolved to Wales, Scotland and Northern Ireland; English local government remains under UK government control (see Appendix 8.A1). English regional government, in the form of non-elected Assemblies and associated Development Agencies, had been in place from 1994, but was dismantled in 2011. Regional powers over sustainable energy in England were limited, but agencies received a small amount of central government funding to support energy governance, and variously established regional energy agencies, sustainable energy partnerships and renewable energy targets (Smith 2007). Currently, English local authorities may collaborate voluntarily through Local Enterprise Partnerships, but these have no direct remit in relation to energy and climate change. We therefore explore differences across the four countries of the UK and among English regions, both in response to the relative emphasis on sustainable energy, and in relation to variation in supportive institutions such as development agencies. Research on climate preparedness in UK urban areas has found that local authorities in England

and Scotland have more developed mitigation and adaptation plans than those in Northern Ireland and Wales (Heidrich *et al*. 2013). In addition, the Scottish Government has set more ambitious climate and renewable energy targets for 2020 than the rest of the UK.

Shackley *et al*. (2002) identified 14 local authorities whose actions through the 1990s positioned them as 'leading the way' on carbon reduction. The authors of that survey suggest the key factors distinguishing the pioneering authorities were: consistent commitment from local politicians and senior officers; in-house committed energy specialists; local cross sector partnerships; linking carbon and energy issues with other local goals including amelioration of fuel poverty, regeneration and business efficiency; and access to finance. These factors are replicated in other recent case-study research (Bale *et al*. 2012; Bolton and Foxon 2014; Bulkeley and Kern 2006; Hawkey *et al*. 2013a) and explored with our data below.

Establishing a measure of local engagement: methodology

To establish a measure of local engagement with energy across all UK local authorities we constructed a new database from a combination of publicly available data sources organised by local authority area, data on low carbon and renewable energy installations, and original data collection, including searches of all 434 UK local authorities' websites. Data were gathered in 2013. We operationalised 'local engagement in energy systems development' in relation to two composite variables: the existence of local authority energy and/or carbon plans, and the number of local energy projects in which the authority has successfully mobilised investment. We then assigned each authority to one of four categories: *energy leaders* (the most engaged), *running hard*, *at the starting blocks* and *yet to join*. The categories give an indication of the extent of local government engagement with energy, and enable us to examine the factors set out above. Category definitions are shown in Table 8.1. We also examined patterns of low carbon and renewable energy deployment across our four categories, asking whether a higher degree of local engagement corresponded to greater deployment of technologies in the area.

We focus on energy and carbon plans as an indicator of both a local authority's *willingness* and *organisational capacity* to engage with localised energy systems. Energy and carbon plans typically include measurement and reporting of energy use and carbon emissions, and outlining carbon reduction targets, management processes and responsibilities for energy. In some cases focus remains within the organisational boundary of a local authority, but in others it extends to cover town- or city-wide energy profiles and identification of ambitious decentralised energy projects. We also focus on investments in energy projects as an indicator of the material result of engagement with energy in *practice*. Data on investment cover a variety of local energy projects (see below) that are not always captured by energy and carbon plans. A fuller description of the data underpinning the research can be found in Appendix 8.A2.

TABLE 8.1 Categories of local engagement in energy system development

Level of engagement	*Category name*	*Definition*	*Operational measure*
Highest level of engagement	*Energy leaders*	Local authorities currently at the leading edge in low carbon energy. There is evidence of strategic planning and multiple investments in energy projects.	Investment in 3+ projects (with or without published Energy and Carbon Plan).
	Running hard	Local authorities with evidence of strategic planning and some investment in energy-related activities. Plans indicate ambition to mobilise further investment.	Investment in 1-2 projects *and* published Energy and Carbon Plan.
	At the starting blocks	Local authorities which have gone some way towards developing commitments and action plans, but for whom implementation may remain aspirational or at early options appraisal or feasibility stage. Those authorities making some investments do not appear to have acted within an overarching strategic plan; those authorities with evidence of strategic planning have not (yet) translated this into investments.	Investment in 1-2 projects *or* published Energy and Carbon Plan.
Lowest level of engagement	*Yet to join*	Local authorities for whom engagement in energy systems is currently very limited or apparently absent, with neither strategic planning nor investment evident.	No investment in projects and no published Energy and Carbon Plan.

How widespread is activity at local government level?

Overall we find that around three-quarters of local authorities show evidence of *some* engagement with energy. Only a third of authorities, however, combine energy and carbon planning with mobilisation of investment in energy projects, and fewer than 10 per cent have successfully developed three or more projects. Nine per cent (or 38) of UK local authorities have mobilised investment in three or more energy initiatives (the *energy leaders*). Twenty-one per cent (or 89) have mobilised investment in one or two initiatives and have also developed an energy and/or carbon plan (our *running hard* category). Forty-seven per cent (or 206) have either mobilised investment in one or two initiatives *or* developed an energy and carbon plan (which we refer to as being *at the starting blocks*). Twenty-three per cent (or 101) do not appear to have engaged with energy and so are categorised as *yet to join*. The geographical distribution of the four categories is shown in Figure 8.1 and Boxes 8.1–8.5 draw out key findings.

Local authority engagement is thus widespread, but shallow as only a minority have developed three or more initiatives, suggesting considerable scope for greater activity; as a minimum, engagement extending across all authorities to the level of at least three initiatives each. Our observation that energy and carbon planning is associated with a larger number of projects per authority (Box 8.1) suggests that in many cases the development of a local plan does have some effect in supporting development of projects. Since more than half of authorities with plans do not appear to have mobilised investment, however (see Box 8.1), plans alone are insufficient to drive further action.

BOX 8.1 ENERGY AND CARBON PLANS AND MOBILISING INVESTMENT FOR ENERGY

Overall, we find around two-thirds of local authorities develop energy and carbon plans while just one-third have mobilised investment in energy projects, demonstrating that planning is more common than successfully mobilising investment. However, we also find a relationship between energy planning and investment in energy projects; as the number of energy initiatives increases so does the likelihood that the local authority has published an energy and carbon plan (see Table 8.2), a relationship that is statistically significant (X^2=9.39, df=2, p=0.008).

TABLE 8.2 Published energy and carbon plan and number of investments in energy projects

Energy and carbon plan?		*No energy investment*	*Investment in 1–2 projects*	*Investment in 3+ projects*	*Total*
No	Count (row %)	101(69%)	40 (27%)	5 (3%)	146 (100%)
	(column %)	(38%)	(31%)	(13%)	(34%)
	Category	*yet to join*	*starting blocks*	*energy leaders*	
Yes	Count (row %)	166 (58%)	89 (31%)	33 (11%)	288 (100%)
	(column %)	(62%)	(69%)	(87%)	(66%)
	Category	*starting blocks*	*running hard*	*energy leaders*	
Total	Count (row %)	267 (61%)	129 (30%)	38 (9%)	434 (100%)
	(column %)	(100%)	(100%)	(100%)	

Local engagement is embedded in devolved and regional government institutions

Engagement varies across the countries and regions of the UK (Box 8.2). In England, London stands out as having the highest levels of both *energy leaders* and authorities *running hard*. London comprises thirty-two borough councils and the City of

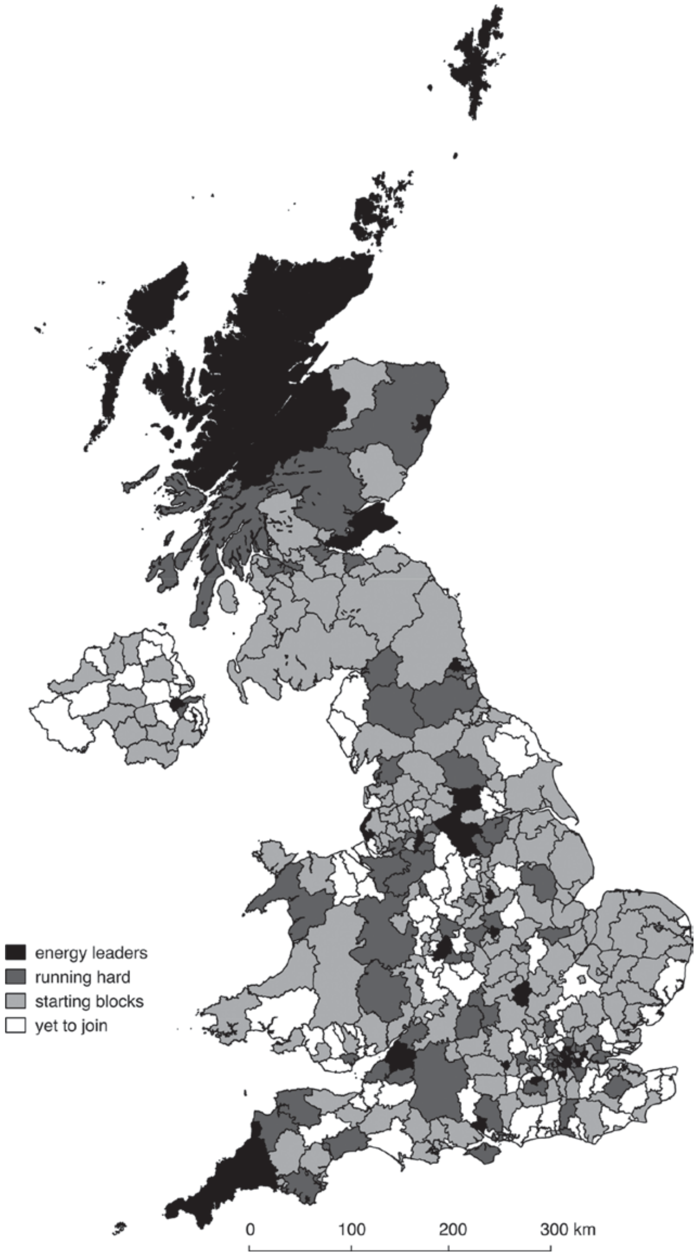

FIGURE 8.1 UK local authority engagement with energy systems. Map shows unitary and lower tier authorities and excludes county councils.

Sources: Contains Ordnance Survey data 2012, 2013; National Statistics data 2013; NISRA data 2013; NRS data 2013. © Crown copyright and database right.

Map created using *QGIS* (QGIS Development Team 2014).

London corporation which fulfils the function of a borough authority for London's financial services; the Greater London Authority (GLA) is a devolved body covering the combined territories of the boroughs and corporation. The GLA articulates a vision for local energy in the capital, aiming for 25 per cent of London's heat and power needs to be met by low carbon decentralised energy systems by 2025, primarily gas-fired Combined Heat and Power (CHP) and district heating, with energy from waste and biomass schemes (GLA 2011). Work on decentralised energy tends to be shared between the GLA and borough authorities; the former takes on tasks common across authorities, such as setting minimum standards for heat networks (GLA 2014), while the latter coordinate and implement particular heat network and related projects. The GLA has drawn on EU funds to develop London-wide decentralised energy schemes, and to coordinate an energy performance contracting approach to energy efficiency. These funds include support for activities of the borough authorities. The combined programmes aim to mobilise around €230m of investment. In addition London occupies a unique structural position in the UK and in global finance markets, which raises land values and attracts relatively high rates of investment, creating more scope than elsewhere for local energy initiatives to achieve financial viability.

A high proportion of *energy leaders* are nevertheless identified in the English region of Yorkshire and the Humber. This may be a legacy of the regional institutions which were dismantled in 2011. These are regarded as having a distinctive approach to sustainable energy; the Regional Development Agency *Yorkshire Forward* for example adopted relatively ambitious climate change targets earlier than other agencies. There is also a local tradition of partnership working across sectors, and ambitions to integrate sustainable energy into economic development by, for example, framing targets as optimising the use of the environment rather than simply protecting it (Roberts and Benneworth 2001; Shackley *et al.* 2002).

Scotland also has a relatively high proportion of *energy leaders* and no authorities *yet to join*. Public bodies in Scotland were particularly successful in securing UK Government Community Energy Programme (CEP) funding for CHP and district heating in the early 2000s (see Chapter 5). Although less than 10 per cent of the UK's population is located in Scotland, almost 60 per cent of CEP grant funding went to Scottish projects, which were supported by a knowledge-sharing network established by Scottish Government. In addition to the more ambitious carbon and renewables targets adopted in Scotland, the Scottish Climate Change Act (2009) includes a duty on public bodies to act in support of the devolved government's climate change targets, a stipulation absent in other parts of the UK. The alignment of devolved and local government around climate change was preceded by the Scottish Climate Change Declaration, launched in 2007 and signed by all local authorities. In contrast with declarations adopted in other parts of the UK, this committed local authorities to developing energy and carbon plans, to embedding climate change mitigation across council priorities, and to providing annual updates on their progress. More recently Scottish Government launched a £20m Local

BOX 8.2 REGIONAL DISTRIBUTION OF ENGAGEMENT

Energy leaders are concentrated in particular regions[2] of the UK. With one-third of authorities classified as *energy leaders*, Greater London has the highest proportion. In Scotland and the Yorkshire and the Humber region almost 20 per cent of authorities are *energy leaders* (compared with 6 per cent across the remaining UK regions). Considering *energy leaders* and those *running hard* together (i.e. all authorities which combine energy investment with energy and carbon planning) these three regions again show the highest levels of engagement. In London 70 per cent of authorities fall in our two most engaged categories, 40 per cent of Scottish authorities and 36 per cent in Yorkshire and the Humber, though on this scale the region with the next highest levels of engagement (the North East) is not far behind with 33 per cent of authorities combining strategic energy planning with mobilisation of investment. We found one *energy leader* in Northern Ireland and none in Wales.

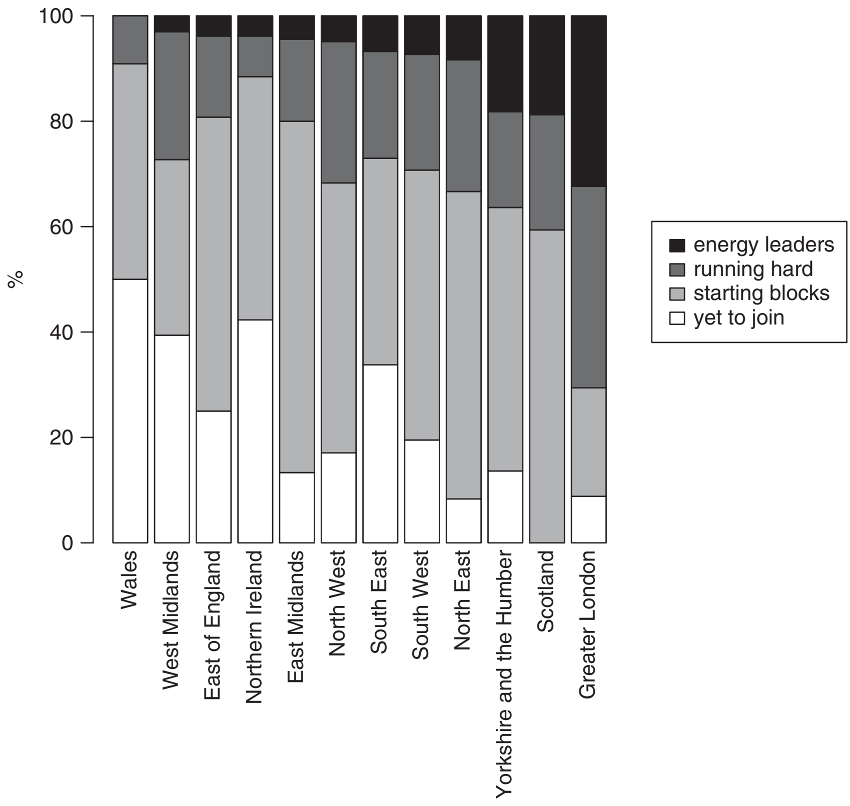

FIGURE 8.2 Proportion of local authorities in each engagement category by UK region.

Energy Challenge Fund to support development of low carbon and renewable energy projects, as well as The Heat Network Partnership for Scotland and District Heating Loan Fund, which are specific to heat networks. While these initiatives are too recent to have translated into projects represented in our data set, they illustrate the consistent interest of the devolved government in channelling at least some of its sustainable energy aspirations through local-scale initiatives.

Larger local authorities tend to show higher levels of engagement with sustainable energy

Local authorities showing the highest levels of engagement tend to be larger than those less engaged; engagement correlates with size of population, corporate energy consumption and corporate CO_2 emissions, supporting the contention that authorities with greater resources at their disposal are better able to develop local energy initiatives (Boxes 8.3 and 8.4). When we compare different types of local authority, we observe patterns consistent with both authority size and a 'London effect' (see Box 8.5).

The exception to this is the pattern of engagement across county councils, which remain a tier of local government in England. A relatively high proportion of these authorities, almost half, combine strategic planning with mobilising investment in initiatives (see Figure 8.5). When we consider only the *energy leaders* category, however, the proportion of county councils is low, despite their large size. The division of statutory responsibilities between county councils and district boroughs thus appears to create fewer opportunities for county councils to develop multiple energy initiatives than single-tier authorities of similar size. This pattern supports the expectation that in many cases local energy initiatives emerge opportunistically from links with statutory functions, rather than having an autonomous, strategic role.

The pattern across the UK suggests a mixture of institutional and contingent factors shaping local authority energy initiatives. Devolved government and the legacy of English regional government provide important support, both politically through articulated visions and practically through funding and capacity building networks. Authorities with overt political commitments to sustainable energy (Box 8.6) also tend to show higher levels of engagement, mobilising investment in multiple projects (*energy leaders*), suggesting that, irrespective of whether energy initiatives form part of a *strategy*, buy-in at senior levels is key to activity. The relationship between political commitment and engagement with sustainable energy implies that a local strategy does have some effect, and that the loosening of the *ultra vires* principle has to a degree created some scope for local entrepreneurialism in energy. Initiatives nevertheless often appear to arise out of an opportunistic link to statutory services. The small proportion of authorities managing to develop multiple energy projects (*energy leaders*), coupled with the repeated case study observation that many local initiatives depend on unusually tenacious 'wilful individuals' (e.g. Collier and Löfstedt 1997; Fleming and Webber 2004; Webb 2015) indicates

BOX 8.3 CORPORATE ENERGY CONSUMPTION AND ENGAGEMENT

Energy leaders tend to have higher corporate energy consumption. Under the definitions of the Carbon Reduction Commitment Energy Efficiency Scheme (Environment Agency 2014), 68 per cent of *energy leaders* are considered large energy users and required to report by the scheme, compared with just 16 per cent (16) of the *yet to join* authorities. For authorities required to report corporate energy-related emissions, we also find an association between engagement category and emissions (Figure 8.3); the median emissions of *energy leaders* (36 $ktCO_2$ in 2011–12) are about twice the median of the *yet to join* group (19 $ktCO_2$). These trends are confirmed as significant by analysis of variance with carbon emissions as the dependent variable (log transformed to correct skewed distribution) and category as an independent variable: $F(3,161)=3.23$, $p=0.023$.

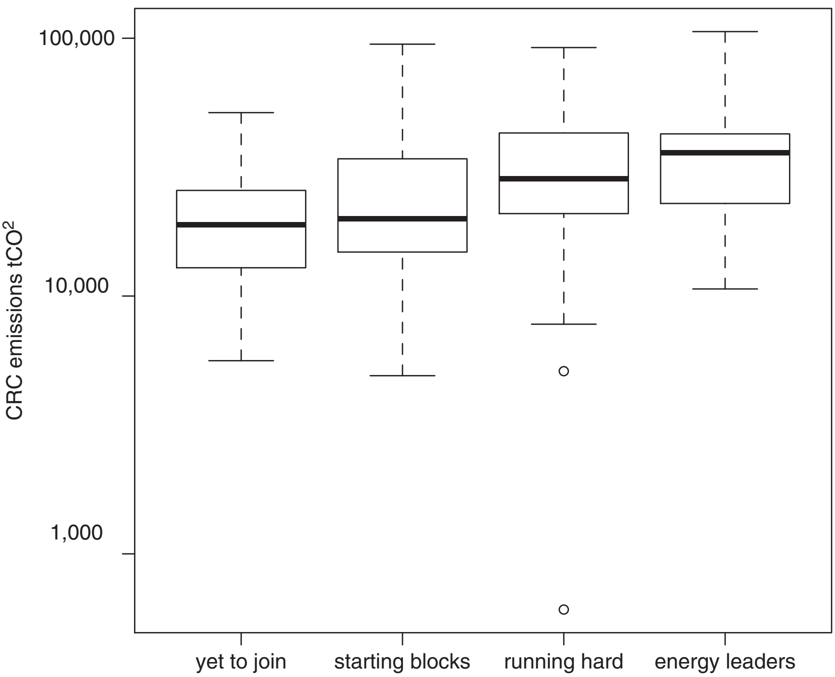

FIGURE 8.3 Reported carbon emissions submitted to the CRC for the year 2011–12, measured in tonnes of CO_2, by engagement category.

BOX 8.4 SIZE OF LOCAL POPULATION AND ENGAGEMENT

Larger population size is associated with higher degrees of engagement. The median population for *energy leaders* is 268,000, while that for *yet to join* is less than half that at 103,000. Local authority population size varies hugely from as little as 2,300 in the Isles of Scilly to over 8m within the Greater London Authority (2012 population figures from Office for National Statistics 2013). These trends are confirmed as significant by analysis of variance with population as the dependent variable (log transformed to correct skewed distribution) and engagement category as an independent variable: $F(3,161)=28.0$, $p<0.001$.

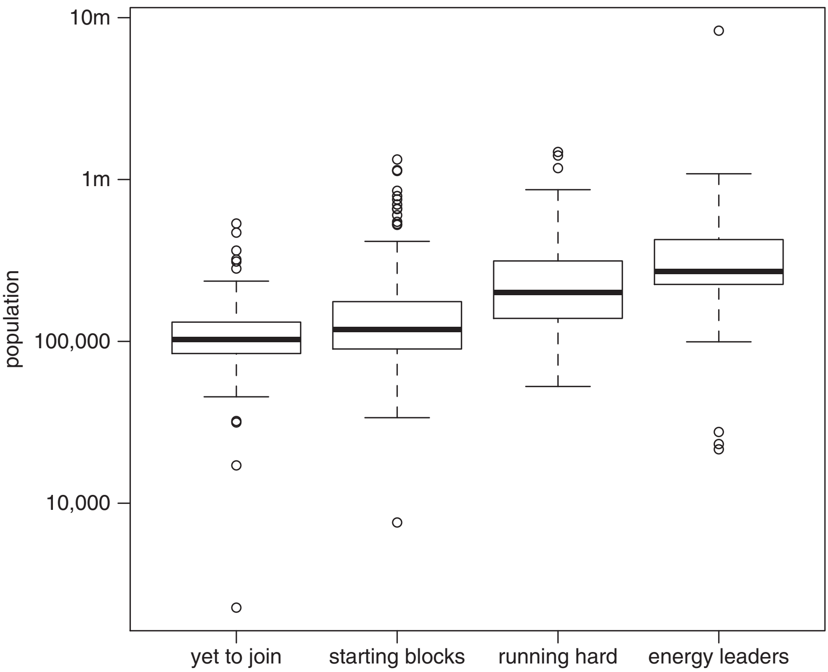

FIGURE 8.4 Size of local authority population by engagement category.

BOX 8.5 TYPE OF LOCAL GOVERNMENT AND ENGAGEMENT

Energy leaders are found across all of types of UK local government with the greatest proportions found among London authorities, metropolitan districts and unitary authorities. The pattern of engagement here may relate to the impact of London regional government and the size of authorities. Metropolitan district boroughs tend to be larger than unitary authorities: the median metropolitan authority population is 275,000 while the median unitary authority population is 141,000. District boroughs, the lower tier authority in the county/district system in England, is the most common type accounting for 46 per cent of all UK authorities and generally has the smallest local population. They are the least engaged with only two of them being categorised as *energy leaders*. County councils, in spite of their large size, tend not to be *energy leaders*, an issue discussed in the main body of the text.

When we look at *energy leaders* and *runners* together, the proportion of authorities falling into one or other of these categories again appears consistent with a 'London effect' and a 'size effect'. London authorities remain the most engaged, being the only group of authorities in which the majority are in one of these two categories. Engagement levels among metropolitan districts and unitary authorities again tend to follow population size (Box 8.4).

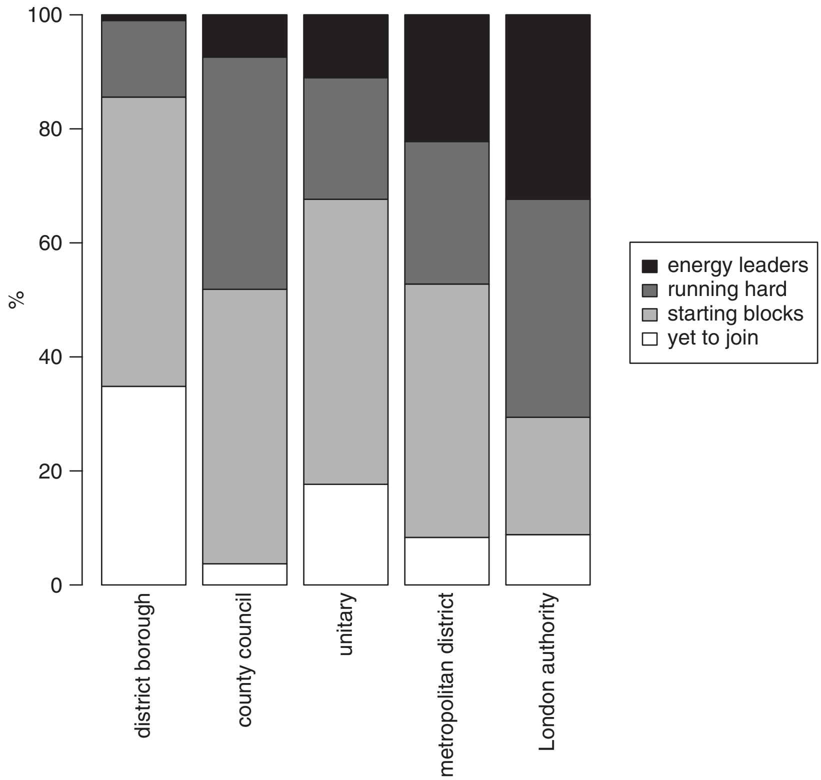

FIGURE 8.5 Proportion of local authorities in each engagement category by type of local authority.

BOX 8.6 POLITICAL COMMITMENT AND LOCAL ENGAGEMENT WITH ENERGY SYSTEMS

We operationalised political commitment conservatively as whether a local authority was a signatory to the EU Covenant of Mayors. This commits local authorities to exceeding European carbon abatement targets, and is increasingly a condition for accessing European funding programmes. In total 34 of the 434 authorities are signatories to the covenant, and engagement levels are high among them: 38 per cent of signatories are *energy leaders* and 65 per cent are either *energy leaders* or *running hard*. By comparison of the non-signatories, 6 per cent are *energy leaders* and 26 per cent are either *energy leaders* or *running hard*.

that such entrepreneurialism remains a niche activity, beset by multiple challenges. Continuity of engagement with energy under this model also appears precarious: of the 14 authorities Shackley *et al*. identified as 'leading the way' in 2002, we categorised 9 as *energy leaders*, 2 as *running hard*, 2 as *on the starting blocks* and 1 as *yet to join*.

What is the scope of activity among the *energy leaders* and what is the scale of their contribution to local energy?

In this section we explore in more detail the different types of energy projects pursued by authorities at the leading edge. Heat is found to be a primary area of engagement, in combination with other initiatives. We then quantify in energy terms, within the limits of available data, the impact of local engagement with heat.

Drivers for engagement

Shackley *et al*. (2002) suggested local engagement with sustainable energy would likely be most effective if linked to a range of other priorities. We conducted a content analysis of strategic documents published by the *energy leaders* to explore what issues these authorities tended to link sustainable energy initiatives to. The most common priorities were supporting or improving the local economy (16 *energy leaders*) and articulating a local vision of the future (16). Eleven *energy leaders* identified both issues. Other concerns were less frequently cited, with four *energy leaders* identifying fuel poverty as a driver, six identifying energy saving and six resource efficiency (including waste disposal). The relative frequency with which *energy leaders* identified economic concerns suggests this link may play a role in the ability of local authority officers to galvanise sufficient support to develop multiple energy initiatives. This interpretation resonates with our discussion of the high levels of engagement in Yorkshire and the Humber, which we suggested may relate to the (now disbanded) Regional Development Agency's distinctive casting of environmental issues in economistic terms (Roberts and Benneworth 2001).

We find that three-quarters of *energy leaders* (29) had developed projects which were directly dependent on central government grants and initiatives (cf. Rydin *et al.* 2013), indicating the limited alternatives available.

Energy leaders engage with multiple technologies

Energy leaders tend to work across a variety of technologies, with some pursuing multiple types and forms of provision. One-fifth of the *energy leaders* had also established dedicated funds to support other actors' local initiatives. These included grants to community groups and revolving funds aiming to stimulate development of local supply chains. Of the 38 *energy leaders,* the majority (33) had developed energy efficiency schemes, primarily targeting the domestic sector (30), but also the public sector (15) and local businesses (14). On the supply side, all but one of the *energy leaders* had invested in technologies generating or supplying heat or electricity, including CHP (30 *energy leaders*), district heating (28), renewables (26) and energy from waste (14). An exclusive focus on either supply-side or demand-side initiatives was rare, with 32 *energy leaders* developing both. Among supply-side activities we found neither electricity nor heat dominant, with many engaged with both. That is, while national policy on sustainable energy is often characterised as only recently discovering heat (see Chapter 4), the most engaged local authorities have been developing heating supply initiatives in parallel with electricity. This is further emphasised by our finding that half of the *energy leaders* are members of the UK District Energy Vanguards Network,[3] a knowledge sharing and co-production network which focuses on district heating.

Energy leaders use a variety of organisational and governance models. Most common are approaches which pass responsibility and control to third parties. These include commercial Energy Services Company (ESCo) models and Private Finance Initiatives (PFI) contracts (11 *energy leaders*), local authority-owned ESCos (6) and community social enterprises such as renewable energy cooperatives (3). While our review of local authority documents was unable to identify delivery vehicles in every case, these findings indicate a tendency to externalise control over initiatives, suggesting that opportunities, and/or motivations, to develop in-house technical expertise are limited (see Chapter 6).

Scale of initiatives in energy leaders' areas

Given limited data on district heating networks in the UK, and the use of incompatible metrics (such as total length of pipework or numbers of customers), it is not possible to quantify the extent of district heating developed by the *energy leaders*. A standard reporting format for CHP has however been developed by the UK Government and data on many non-industrial CHP systems are available through the CHP Focus programme,[4] and initiative of the UK Government Department for Energy and Climate Change (DECC). Fifteen *energy leaders* are shown as CHP generators in the Focus database. The median scheme is small (at just $210kW_e$) and just six *energy leaders* have over $1MW_e$ of CHP. Relatively large energy from waste plants in Nottingham ($11MW_e$) and Sheffield ($22MW_e$) contribute to an overall aggregate capacity across the *energy leaders* of $56MW_e$. If we convert these electrical capacities to an estimate of annual CHP heat output,[5] we find that only a small fraction of local heat demand[6] is served by schemes led by *energy leaders* (median 0.1 per cent, mean 0.9 per cent).

CHP schemes developed or hosted by local authorities are not the only form of local CHP. We examined the deployment of non-industrial CHP (again, using DECC's CHP Focus database) to compare local energy led by other actors across our categories of local authority engagement.[7] We find a larger number of CHP generators in the *energy leaders'* territories: 68 per cent of *energy leader* areas have at least one CHP generator compared with 56 per cent of *running hard* and fewer for the less engaged categories; where CHP is present there are typically more generators in the *energy leaders'* areas, with an average of 2.9 compared with 2.0 for the *running hard* category and fewer for the less engaged categories; the mean size of CHP generators in *energy leaders* areas is greater (1.4MW_e) than other areas (770kW_e).[8,9]

This correspondence between local non-industrial CHP and local authority engagement may have two mutually compatible explanations: greater deployment of CHP by other actors may contribute to local authority interest in energy; or an engaged local authority may contribute to a more conducive environment for CHP deployment, for example, by adopting supportive planning policies (Hawkey *et al.* 2013b). In quantitative terms, the deployment of CHP by other actors in *energy leaders'* areas accounts however for only a small proportion of total heat demand in these areas (median 0.3 per cent, mean 0.7 per cent). Thus, while our finding that only 9 per cent of local authorities have engaged with multiple local energy initiatives indicates there is considerable scope for other local authorities to match this performance, and while heat appears to play just as important a role among the most engaged authorities as electricity does, the quantitative impact of these interventions remains small.

Case studies of UK local authority engagement with energy

The following case studies exemplify the themes discussed above in relation to specific projects and contexts.

Leicester City Council

Leicester, a city of 330,000 in the East Midlands is often identified as one of the UK's 'pioneering authorities' in energy and climate change action both because of its 'early mover' status and its continued engagement (e.g. Bulkeley and Kern 2006; Collier and Löfstedt 1997; Fleming and Webber 2004). As an 'early mover', Leicester was designated an Environment City in 1990; received a Local Government Honours award at the Rio Earth Summit in 1992 (Lemon *et al.* 2013); adopted an ambitious 1994 target of 50 per cent reduction in CO_2 emissions by 2025 (1990 baseline); and became European Sustainable City in 1996 (Roberts 2000), when it formed the Leicester Energy Agency. The agency is part of the Council and uses a range of European funding streams to support energy efficiency improvements by businesses, community groups and householders. By 1997 12 per cent of the Council's energy was provided through a renewable energy programme (Roberts 2000: 26). The Council introduced sophisticated energy monitoring for council buildings (Bulkeley and Kern 2006) and has made innovative use of aerial photography to target insulation schemes for funding by the UK government energy efficiency obligation on energy suppliers (see Lemon *et al.* 2013 for a fuller discussion of Leicester's 'Hot Lofts' scheme). In 2005 the Council was awarded Beacon status for sustainable energy and joined the EU Covenant of Mayors in 2009. The Council is one of 11 cities making up the Board of Directors for the Energy Cities network.[10]

District heating ambitions in Leicester have a relatively long pedigree, having been incorporated in 1981 into the 'Lead Cities' programme, a central government initiative which aimed to stimulate large scale CHP district heating systems in response to the 1970s oil crises (see Chapter 5). Work did not begin on the system in Leicester until 1987, and initially focused on several unconnected social housing sites with the ambition that these would eventually extend and link up to form a system large enough to absorb heat from a local combined cycle gas turbine (Babus'Haq and Probert 1996). In the context of central government policies to privatise and liberalise energy systems (see Chapters 2 and 5), the city's ambitions were however thwarted, and district heating remained a patchwork of unconnected small satellite schemes for the next 20 years.

In the mid-2000s the Council revisited the potential for expanding district heating, and in 2010 entered a 25-year design-build-finance-operate contract with Cofely District Energy Ltd (a GDF Suez subsidiary company). Leicester District Energy Ltd, established as the same type of Special Purpose Vehicle used for the Birmingham District Energy Company (see Chapter 7), owns and operates all council heat networks in the city and has upgraded the older island networks. District heating has been extended into the city centre, connecting council buildings and the University of Leicester campus. The University energy centre hosts $5MW_e$ gas-fired CHP, while $50MW_{th}$ gas boilers are located on six sites and a 100kW wood pellet biomass boiler serves 94 houses on a social housing estate (Cofely GDF Suez 2015; University of Leicester 2012).

Financing for Leicester District Energy Ltd included £14m from its parent company. The scheme provided a means for GDF Suez to comply with the energy efficiency obligation imposed by UK Government on large energy suppliers (the Community Energy Saving Programme, CESP[11]). The estimated financial value of the CESP contribution was £1m (Leicester City Council 2010), though the price of carbon within CESP rose considerably from around £20 per tonne in 2010 to around £50 in 2013 (DECC 2014) suggesting that the avoided cost to GDF Suez may have been considerably higher than the £1m grant.

Leicester demonstrates, and has received recognition for, a high level of entrepreneurial engagement in sustainable energy, but also illustrates the dependence of UK cities on a shifting patchwork of national support programmes, which makes a locally determined, consistent and strategic approach very difficult to maintain and build on. This is apparent in the waxing and waning of district heating developments in parallel with intermittent central government initiatives over 30 years. While the council has drawn successfully on European funding streams, Fleming and Webber (2004) conclude that this has produced a funding-led opportunistic approach rather than a coordinated strategy. Lemon *et al.* (2013) estimate the energy and carbon impacts of the city council's initiatives as limited: extension of the heat network for example is estimated to result in city carbon savings of around 1 per cent.

Aberdeen City Council

Aberdeen's economy is intertwined with, and significantly reliant on, the energy industries due to its major role in the North Sea oil and gas sector. As well as the district heating initiatives described in Chapter 7, Aberdeen City Council coordinates a complex public-private partnership, the 'Aberdeen Hydrogen Project', which aims to support development of a regional hydrogen economy. The project converts electricity generated at grid-constrained Aberdeenshire wind farms into hydrogen, and transports it to Aberdeen for use in ten hydrogen fuel cell buses. With a budget of £19m the initiative brings together local, national and international collaborators across the North Sea Region public, private and research sectors.[12] The then Council leader summarised its significance for the Council and City:

> We will have the world's largest fleet of hydrogen fuel cell buses running on Aberdeen's streets, which will help us to not only realise our aspiration of becoming a world-leading city for low carbon technology, but also of maintaining our position as a leading world energy city.
>
> *(quoted in Aberdeen City Council 2015a)*

Whereas Aberdeen's district heating schemes prioritise amelioration of fuel poverty, with carbon saving as a secondary goal (see Chapter 7), the Hydrogen Economy initiative is a multi-stakeholder collaboration prioritising economic development. The hydrogen project has not been integrated with district heating schemes, beyond noting the potential future use of hydrogen as an additional fuel source for heat networks. This need not be interpreted as a *failure* of coordination but as illustrating the project-based character of many forms of local engagement. The nascent status of both district heating and the hydrogen scheme afford few opportunities for mutually supportive integration. While Aberdeen's hydrogen initiatives are embedded in a vision of energy system transformation, in an economic development agenda, the present reality of limited local authority influence over energy restricts opportunities to progress.

Cambridgeshire County Council

Cambridgeshire is a county council in the East of England with a population of 630,000 in five district boroughs. In partnership with the boroughs, the County Council is prioritising development of an investment fund for low carbon and renewable energy, including district heating. Early proposals for the project, 'Mobilising Local Energy Investments' (MLEI), were to create a company limited by guarantee which would receive money from local developers discharging their obligations under a national 'zero carbon homes' policy. The 'Allowable Solutions' mechanism would charge developers a standard rate per tonne of carbon above the zero carbon standard for new housing (see Chapter 10). The fund was intended to ensure that money generated from housing development was recirculated into the local economy, and to ensure that local authorities were able to control the 'solutions' adopted (French 2012).

As the Allowable Solutions policy has developed, however, the control exercised by local planning authorities has been reduced in order to give developers access to a UK-wide market in solutions' providers (Department for Communities and Local Government 2014b). MLEI has thus been significantly reconfigured from a mechanism to direct funding into local priorities to a scheme to mediate between local projects and a range of public and private investors. In 2012 the project received Intelligent Energy Europe funding of €1.1m which it seeks to leverage to a minimum of €17m investment in retrofit of social housing and public sector buildings for energy efficiency (Frank 2013). The County Council's proposed approach is to use energy performance contracting to draw third party finance into energy efficiency for local schools and council buildings, alongside loans from the investment fund (Cambridgeshire County Council 2014).

The recasting of the MLEI has been accompanied by a shift in technologies targeted. While heat networks (i.e. relatively *large* projects) were the dominant component of early plans, with the fund providing the low cost long-term finance required (as discussed in Chapter 6), current activity focuses on aggregation of *small* projects to a scale suitable to external investors. MLEI *has*, however, undertaken development work on a $12MW_e$ solar photovoltaic farm, having been granted a 'Contract for Difference' by the UK Government under market reforms intended to increase investment in renewable electricity. In contrast with heat network investment, the Contract for Difference mechanism guarantees a fixed electricity sales price over 15 years.

Conclusion: what does this mean for local government engagement and its likely trajectories?

The picture that emerges from our population survey of local authorities is one of widespread local ambition to contribute to development of environmentally sustainable energy systems. This is exemplified by the fact that two-thirds of authorities have developed an energy and carbon plan. Progress in development of projects is more limited, however, with only one-third of authorities showing evidence mobilising investment, and only one in eleven authorities successfully developing three or more initiatives (the *energy leaders*).

Local authority engagement emerges from the interplay of voluntary action, including political and officer commitments, local resources and capabilities, local opportunities (particularly those linked to statutory activities) and embedding within European and national government programmes. The small proportion of *energy leaders* indicates that these factors are not easily or routinely aligned. Our observation that 5 of 14 local authorities identified as 'leading the way' in 2002 are no longer in leading positions also suggests that local engagement has a precarious character. One dimension of this precariousness is the unpredictable and intermittent nature of central government initiatives, which contributes to undermining local capacities to maintain a consistent strategy (Bolton and Foxon 2014; Fleming and Webber 2004; Hawkey 2012; Wiltshire *et al.* 2013). A second dimension is the position of sustainable energy as statutorily *permitted* but not statutorily *required*, making engagement with energy a likely casualty when budgets are tight. Indeed, since the data we report on were gathered, at least one of the *energy leader* group appears to have significantly scaled back its staff resource allocated to energy. The small scale of many local initiatives, relative to local energy demand, contributes a third dimension: interventions are rarely significant in altering the local conditions for further integrated development. That is, the engagement we observe does not change or challenge incumbents in the UK energy system in any significant manner. This contrasts, for example, with decisions by German municipalities to take control over local networks as attempts to govern and direct the integration of decentralised energy generators (Moss *et al.* 2014).

The propensity to outsource energy initiatives to third parties contributes to these limits, by restricting the development of local authority capacities and control over the systems developed. The importance in the UK of the 'enabling' mode of local governance, whereby local authorities act to create conditions within which other organisations may take action or provide services (see Chapter 2) contributes both to the propensity to commission third parties to handle energy initiatives and to difficulties integrating energy projects initiated by different statutory service specialties.

The pattern of activity suggests that local authority engagement with sustainable energy struggles to advance beyond the exploitation of marginal or niche opportunities. Set against this, however, is the scope for successful projects to build local political capital and confidence among senior management. Projects also create templates which initiatives in other places may use (cf. Scottish Futures Trust 2015). Progress in local energy systems may accelerate relative to the pattern since the 1990s and early 2000s, but this is unlikely to happen spontaneously. The role of central and devolved governments in extending and institutionalising local authority energy activities is likely to be critical, given the lack of local autonomy and discretion over budgets and services. One way to scale up the local contribution to low carbon energy and energy saving could be for central government to signal its commitment by introducing a statutory duty with commensurate funding, as proposed by the UK Committee on Climate Change (2012). Such an approach, however, is in tension with current national political discourses of austerity and restraint in public spending. An alternative approach, in light of our finding that devolved and regional government plays an important role where engagement levels are high, is the substantive devolution of powers from UK Government in a more federal structure. This could provide significant means for local capacity development, in relation to integrated energy and spatial planning for a low carbon economy and society, in a coordinated UK strategy to meet statutory carbon targets.

Notes

1 For an account of these changes in relation to local energy, see London Energy Partnership (2007).
2 We use the European Union Nomenclature of territorial units for statistics (NUTS) level 1 areas to identify regions.
3 The Heat and the City project convenes the network jointly with a practitioner colleague (www.heatandthecity.org.uk/dh_vanguards_network).
4 See http://chptools.decc.gov.uk for more detail on CHP Focus. The programme's records are likely to under-report installations because operators can withhold their details.
5 Using table 7.8 of the 2013 Digest of UK Energy Statistics, this ratio was calculated as the sum of heat output for all non-industrial CHP installations over the ten-year period from 2003 to 2012 (inclusive), divided by the sum of annually recorded electrical capacities for the same installations over the same period. This gave a value of 6,765$kW_{th}h$ of heat for every 1kW_e installed.

6 Local heat demand was estimated on the basis of sub-national energy consumption statistics for 2011, https://www.gov.uk/government/statistical-data-sets/mlsoa-electricity-and-gas-2011.
7 This analysis excludes CHP installations identified with local authorities as these contribute to the definition of our categories of engagement.
8 The pattern outside the *energy leaders* was slightly higher than average in *starting blocks* areas (890kW$_e$) than *running hard* areas (770kW$_e$), though all categories had lower averages than the *energy leaders*.
9 A similar analysis looking at small scale renewables (under 50MW$_e$) shows slightly above average installed capacity in *energy leader* areas, though the association was not significant.
10 Established in 1990 Energy Cities is the 'European association of local authorities in energy transition': www.energy-cities.eu/.
11 This is the same programme under which the Wyndford scheme discussed in Chapter 9 was supported.
12 Partners are: Aberdeen City Council (£2m), Fuel Cell and Hydrogen Joint Undertaking (£8.3m), Scottish Enterprise (£1.7m), Scottish Government (£1.7m), Scotia Gas Network (£0.2m), Scottish Hydro Electric Power Distribution (£0.75m), Stagecoach and First Bus (£2m) and the UK Technology Strategy Board (£2.4m). As part of the Interreg IVB North Sea Region Programme, HyTrEc also receives ERDF funding (see Aberdeen City Council 2015b).

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Appendix 8.A1: Overview of local government structure

Local government structure in the UK is complicated but is broadly split between a single and two tier system of governance. As a policy area local government is devolved in Wales, Scotland and Northern Ireland where all local authorities are single tier authorities, known as unitary authorities. Unitary authorities are responsible

TABLE 8.A1 The different types of local government across the UK, their responsibilities and their number. The main areas of local government responsibility are education, transport, strategic planning, economic development, planning applications, waste management, social care, libraries, housing, council tax, leisure and recreation, environmental health.

Country	*Local authority type*	*Tier*	*Main responsibilities*	*N. of authorities*
England	Unitary	single	All main service areas	56
	Metropolitan district borough	single	All main services areas. Transport and waste may be coordinated via a single purpose authority. Combined authority may also coordinate these, economic development and strategic planning.	36
	County council	tier 2	All services except housing, planning applications and council tax.	27
	District borough council	tier 1	Main responsibilities are in housing, economic development, council tax, planning applications, waste collection.	201
	London borough	tier 1	All services except GLA strategic functions. Waste may be coordinated through single purpose waste authority.	32
	Greater London Authority	tier 2	Within GLA Group structure strategic role in transport, spatial planning, housing, economic development, environment (including climate change, energy and waste), culture, public health, policing and fire services.	1
	City of London Corporation	tier 1	Same as London boroughs plus responsibilities for policing, as port health authority, promotion of financial services in City of London and City Bridge Trust.	1
Northern Ireland	Unitary	single	Main responsibilities in waste, environmental health, leisure and recreation, also role in economic and community development.	26
Scotland	Unitary	single	All main services areas plus community planning approach.	32
Wales	Unitary	single	All main service areas.	22

Source: Adapted from Slack and Côté (2014).

for delivering all local services in housing, education, social care, planning, transport. Local authorities in Northern Ireland however have fewer overall responsibilities; for example, they are not responsible for housing or education (though at the time of writing local government in Northern Ireland is in the process of being restructured). In England, the single and two tier systems operate in different places. There are two types of single tier authority in England: for some cities all local services are delivered by a single unitary authority; other cities are split into several jurisdictions, each served by a different metropolitan district authority. In the two tier system responsibility is split between multiple small lower tier authorities and a single large upper tier; in London this is delivered through the London boroughs and City of London Corporation (lower tier) and Greater London Authority (GLA) (upper tier). Outside London district boroughs are lower tier and county councils upper tier where, for example, education and waste management are upper tier responsibilities and waste collection lower tier. Table 8.A1 summarises the responsibilities of each kind of authority.

There are several exceptions and variations to this general structure. For example, in London the lower tiers of the boroughs and City of London Corporation have slightly different division arrangements with GLA, and some services, like waste management, are coordinated through waste partnerships though strategic responsibility remains lies with GLA. Outside London, metropolitan boroughs are very similar to unitary authorities but have special purpose authorities for strategic areas like transport. Metropolitan districts increasingly work together in clusters through Combined Authorities which were established in 2009.

Appendix 8.A2: Data used in the research

Strategic energy planning was measured through evidence of a published local authority Energy and Carbon Management Plan collected via online searches of local authority websites. Investment in energy initiatives was measured through extracting local authority investments in energy projects from 15 databases on UK and European energy programmes and operational energy schemes (such as CHP, renewable electricity generation and urban energy retrofits). We selected data sources representing external sources of finance and which therefore does not capture energy projects that are solely financed from internal budgets. We chose this because LAs do not have any core budgets for energy meaning we can expect local authorities to be heavily reliant on external finance, predominantly UK and European funding programmes, as one of the main sources for financing energy projects. A small growing number of authorities are however raising private finance for energy projects (see Chapters 6 and 7; Hannon and Bolton 2015; Hawkey *et al.* 2013) but in these cases they have nearly always obtained grant funding for a component of the energy project which would be captured through this route of data gathering. To ensure the data are as comprehensive as possible we combined funding data with three data sets on operational energy schemes. This provides information on energy schemes that is agnostic to the source of finance to act as proxy measures for investment (Table 8.A2).

TABLE 8.A2. Data sources for measuring local authority investment in energy.

Dataset	*Source*	*Operational measure*	*Type of local energy activity*	*UK Coverage*	*N. LAs in dataset*
CHP Focus Database	DECC	Named organisation operating CHP (any capacity) for sites identified as "Transport, commercial, administration etc."	CHP	UK wide	48
CLUES Database	CLUES (UCL)	Lead organisation	Range of projects (mostly EE in housing including retrofitting, new build, demand management & district heating)	UK wide	42
ELENA Fund	EIB, EC	Secured investment	Support for city-wide investment in EE & decentralised energy	UK wide	20*
ERDF Funds 2007-2013	EC	Secured investment	Range of projects (mostly EE housing retrofit & environmental performance of businesses)	UK wide	31
EST District Heating Map of Scotland	EST Scotland	Named organisation for DH with operating capacity of 1,000MWh a year & above	District heating	Scotland	7
EU Funded Projects (1)	EC	Lead organisation	Range of projects funded under programmes including FP7 and Intelligent Energy Europe	UK wide	25
EU Funded Projects (2)	EC	Partner organisation	As above	UK wide	15
Future Cities Demonstrator Programme	TSB	Secured investment	Host demonstrator for small or large scale demonstrator for 'smart solutions' including in energy, transport, buildings, waste	UK wide (targeted to cities)	4

(continued)

TABLE 8.A2 (*cont.*)

Dataset	*Source*	*Operational measure*	*Type of local energy activity*	*UK Coverage*	*N. LAs in dataset*
Green Deal Pilot Cities	DECC	Secured investment	Development of green deal proposals & to fund capital works for EE in homes	England & Wales	7
Green Deal Pioneer Places Fund	DECC	Lead organisation	Promotion of Green Deal including free energy assessments & 'demonstrator' EE improvements	England	38
JESSICA fund	EC	Secured investment	Sustainable urban development	UK wide (targeted to cities)	4
Low Carbon Infrastructure Fund	HCA, DCLG, DECC	Secured investment	CHP/District heating	England	11
Low Carbon Pioneer Cities – Heat Networks Project	DECC	Secured investment	Heat networks development support	England	7
Ofgem Renewables and CHP Public Register	Ofgem	Named organisation for RO/REGO	Landfill gas, wind, hydro, solar PV	UK wide	10
UK Community Energy Programme	Defra	Secured investment	CHP/District heating	UK wide	21

Data was gathered in summer 2013.

Key: CLUES=Challenging Lock-in through Urban Energy Systems, DCLG=Department for Communities and Local Government, DECC=Department of Energy and Climate Change, Defra=Department for Environment, Food and Rural Affairs, EC=European Commission, EE=Energy Efficiency EIB=European Investment Bank, ELENA=European Local ENergy Assistance, ERDF=European Regional Development Funds, EST=Energy Saving Trust, HCA=Homes and Communities Agency, JESSICA=Joint European Support for Sustainable Investment in City Areas, LA=Local authority, Ofgem=Office of Gas and Electricity Markets, RO=Renewables Obligation, REGO=Renewable Energy Guarantees of Origin, TSB=Technology Strategy Board, UCL=University College London.

* Includes London Boroughs which have been supported via the two ELENA programmes in London.

PART IV

Affordable and sustainable warmth for housing

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9

PAYING FOR ENERGY

Understandings of home, well-being and affordable warmth

David McCrone

Keeping warm at home is fundamental to participation in advanced societies, but in the face of declining incomes in real terms, increasing inequality and rising energy prices access to, and paying for, energy has become a major UK political and social issue. In this chapter we examine how people on a Glasgow housing estate experience living through housing innovation and the replacement community energy systems for heating. The chapter focuses on questions about the affordability and effectiveness of new heating which is intended to offer energy and cost-saving relative to old expensive and ineffective electric storage heating.

Why should this matter, and what does it tell us about practices of energy provision, innovation and use in cities? In the first place, heating and electricity costs are an increasingly significant component of incomes of British households. Domestic energy bills (gas and electricity combined) increased by 24 per cent between 2008 and 2012 (DECC 2013), and analysis by the UK charity Citizens Advice found that the major energy suppliers had increased prices by 37 per cent between 2010 and 2012.[1] The UK Office for National Statistics showed that expenditure on housing, fuel and power[2] reached its highest level since current recording methods began.

Being fuel poor

The rapid rise in fuel prices, and relative decline in incomes plus increased unemployment, has renewed concerns about the affordability of household energy particularly for those getting by on very low incomes. The fuel poverty indicator has proved politically contentious, given declining incomes and rising energy prices. The UK Department of Energy and Climate Change (DECC) instigated a review, with the resulting report predicting that, far from being eliminated, between 7.8 and 8.9 million people in England would be living in fuel poverty by 2016 (Hills 2012). The Hills report argued that the standard measure of fuel poverty[3] required revision, because it includes people who are not poor overall, while ignoring some low-income families. The UK Government has now adopted Hills' recommended definition.

In its final report, the Hills report observed:

> fuel poverty is a major social problem, causing considerable hardship and negative health impacts, as well as impeding efforts to reduce carbon emissions. It is also widespread. Using the latest official data our recommended indicator shows that more than 7 million people were affected in England in 2009, living in nearly 3 million homes. The fuel poor faced costs which were £1.1 billion higher than would be the case if their bills were at the level faced by typical households (generally living in larger homes and with bigger incomes).
>
> *(Hills 2012: para 62)*

Hills predicted a deteriorating situation by 2016 when there could be nearly more than 200,000 more households in fuel poverty, and a fuel poverty gap more than 50 per cent larger than in 2009.

The devolved[4] Scottish Government's Fuel Poverty Forum, which includes such members as Age Scotland, Poverty Alliance, Scottish Gas and Scottish Power, has continued to use the traditional definition of fuel poverty, because of its simplicity in capturing all fuel poor groups. The Forum (Scottish Fuel Poverty Forum 2012) concluded that, while 28 per cent of households in Scotland were fuel poor in 2010, this had risen to 35 per cent in 2011. The Scottish Government's House Condition Survey for 2013 found that

> Between 2012 and 2013, fuel poverty increased by 4 percentage points from 35.2% to 39.1%. This represents an increase of around 100,000 households from the previous year, reaching 940,000 in 2013. Around 252,000 of these households (10.5%) were in extreme fuel poverty. This increase was driven by a 7% increase in fuel prices between 2012 and 2013.
>
> *(Scottish Government 2014)*

Furthermore, the Scottish Government's report on Severe Poverty in Scotland (Scottish Government 2015) showed that as many as six in ten people who were in 'relative poverty' (below 60 per cent of the UK median income) were in 'severe' (below 50 per cent) or 'extreme' poverty (below 40 per cent). Factoring in housing costs made the extent of severe and extreme poverty still more evident. It concluded:

> Those in poverty in 2012/13 are more likely to be in extreme low income than in 2002/3. This is especially the case after housing costs: in 2012/13, 50 per cent of all people in poverty lived in extreme low income after housing costs, compared with 36 per cent in 2002/3.
>
> *(Scottish Government 2015: 4)*

The relationship between fuel poverty and poverty *tout court* is complex. Nevertheless, access to energy, like access to decent housing, is a function of life chances which are, by and large, determined by social class. Limited ability to pay for domestic energy for heat and power signifies lack of personal autonomy, relative exclusion from the highly valued status of the 'sovereign consumer', and dependence on residualised welfare in a disciplinary state (Bauman 1998). Rather than tackling structural inequalities in society through macro-economic policies, and progressive taxation, neo-liberal politics such as those predominant in the UK have focused on treating symptoms of the problem, including 'fuel poverty' (Boardman 1991), which is considered to be remediable through housing stock upgrades, rather than wider societal reform. Successive programmes, funded sometimes through general taxation and more recently from levies on energy bills, have pursued improved standards for social housing, including replacement heating systems, draught proofing and building insulation.

In a cold climate like the UK's, such measures are valuable in their own right: the need for adequate heating is considerable. They do not however address wider issues of structural inequality and the potential difference between responses to relative poverty per se as opposed to the physical health impacts of cold housing (Gilbertson *et al.* 2012). There is evidence, for example, suggesting that low-income households ration energy use: 'the poorest 10% of households use, on average, only 43% of the energy used by the richest 10% of households' (Druckman and Jackson 2008: 3183). This may mean the poorest households live in uncomfortably cold houses leading to potential adverse effects on health (Liddell and Morris 2010). This can be damaging to well-being when coupled with the often continuing struggle to manage on very low incomes which serves to compound the physical damage of cold living conditions.

Anderson *et al.* make the general comment:

> Households who cannot afford to heat their homes adequately endure the winter months as best they can, using their heating intermittently or only when it is most needed, limiting their domestic lives to only one or two rooms, and wrapping up in extra clothes and blankets. All too often, life becomes a misery, physical health problems worsen and social isolation is exacerbated. Households who were in the greatest financial difficulty were the most likely to have turned their heating down or off, and to be living in cold or damp homes.
>
> *(Anderson et al. 2012: 50)*

While 'fuel poverty' has generated considerable political controversy, as well as debate about how to measure it technically, we know less about how these issues evolve as changes to energy conservation and provision are provided by a registered social landlord and an energy company. This chapter focuses on energy costs and the coping strategies employed by people living on a north Glasgow estate, one of the 10 per cent most deprived areas in Scotland.[5]

Transforming the estate

Glasgow, the largest city in Scotland with a population of just under 600,000, has undergone radical economic and social transformation since 1961 when it had a population of 1 million (Damer 1990; Mavor 2000). The decline of shipbuilding and heavy engineering in the post-war period helped to fashion a 'post-industrial' city based on commerce and culture, marked by the declaration of Glasgow as 'European City of Culture' in 1990. As in the UK overall, inequalities in incomes have widened over the last 30 years, as have inequalities in health, and Glasgow has disproportionately high levels of mortality relative to other UK cities with comparable socio-economic profiles (Walsh *et al.* 2013). Its public housing stock has been subject to successive programmes of demolition, rebuilding and renovation. The introduction of a 'Right to Buy' scheme for housing tenants by the UK Government in the 1980s resulted in sale of the better quality public housing, with more vulnerable households left in lower standard accommodation (Clark and Kearns 2012). The majority of social housing in the city had been owned by the municipal authority, which struggled to finance improvements. In 2003 its 80,000 properties were transferred to the Glasgow Housing Association. Other public housing in Glasgow, including the estate which is the subject of our study, was owned by Scottish Homes;[6] this stock was transferred to smaller housing associations as part of government housing quality improvement policies.

The Wyndford estate, in North Glasgow, was built in the 1960s by Scottish Special Housing Association (SSHA), the predecessor of Scottish Homes, and in 1968 won The Saltire Society award for Good Design. The estate was purchased by Cube Housing Association in 1994. It comprises around 1,900 houses, distributed among 8, 9, 14 and 26 storey blocks, as well as 4 storey 'walk ups' and maisonettes.[7] In the winter of 2012 the Housing Association commenced a major refurbishment programme. This included the replacement of the original electric (night storage) heating by a gas-fired community heating system with new radiators, as well as upgraded standards of building insulation through external cladding, enclosure of some balconies and window replacement. The primary goal of the renovation was the reduction, if not resolution, of fuel poverty, alongside energy saving in line with UK and Scottish climate change policies. The housing association also calculated that it would not be able to comply with the Scottish Housing Quality Standard without replacing the storage heating with a lower cost system.

The Housing Association sought a business model in which they would not play a role in the selling of energy, nor be exposed to business risks such as changing energy prices or bad debt (see Chapter 6). They engaged with the utility company SSE, one of the six major energy firms in the UK, developing a concession model: SSE would design, construct and operate the system for 30 years, after which it would be handed back to Cube Housing Association in good working order.

The concession agreement governs the heat tariff SSE charges. This comprises a fixed and a variable element and was agreed through negotiation between Cube and SSE. The variable element is calibrated to be equivalent to the average gas tariff in Glasgow (accounting for differing factors between gas and district heating, such as the assumed efficiency of a domestic gas boiler). The fixed element, or standing charge, varies between tenants and owner-occupiers, the latter paying a higher charge which includes contributions to a capital replacement fund. Tenants' contributions to this fund are paid by the Housing Association.

The scheme was financed in part under the Community Energy Saving Programme (CESP), a UK-wide scheme that required energy companies to achieve carbon savings in deprived areas. CESP funding was provided by a different major utility, British Gas, which fully funded the insulation of the multi-storey blocks and provided around a fifth of the heating system's £15m capital cost. The remaining upfront costs were financed from the Housing Association's own resources and a contribution from SSE. While CESP funding was crucial to the scheme's financial model, it also created complications with lengthy negotiations followed by a rush to install the scheme before the CESP deadline at the end of 2012 (see Chapter 5). The time pressure contributed to difficulties in the chain of sub-contracting, resulting in some disruption and poor quality work to some of the flats, and the eventual dismissal of one of the sub-contractors.

The network is supplied by a 1.2MW gas CHP engine with three 4.5MW backup/peaking gas boilers, and a thermal store (120,000 litres). Electricity from the CHP is not supplied specifically to the estate but is exported via the public network. The energy centre is sited beside a disused football pitch on the estate, and 2.7 km of underground piping distributes heat to the flats and maisonettes on the estate. The estate neighbours a large supermarket which was being renovated at the same time, as well as a new housing development and a swimming pool. These were identified during early project development as potential additional connections which could improve the network's load balance (see Chapter 6). However, the network has not been extended beyond the housing estate.

The renovation programme set the context for our interviews with tenants, which took place immediately prior to and, in some cases, during that process in late 2012. After conducting a small number of informal pilot interviews, we developed a structured questionnaire which was used for face-to-face interviews with 154 people who rented housing from the Association.[8] The interviews lasted on average 30–45 minutes and explored experiences of, attitudes to and satisfaction with their housing, the heating system and its replacement, and spending on energy vis-à-vis household budgets. We also asked residents about their health histories, and the sense of 'ontological security' which housing might confer (Dupuis and Thorns 1998). A few months after the tenant survey, we carried out 50 interviews with owner-occupiers (1 in 6) on the estate, two-thirds of whom had bought their house under right-to-buy legislation, and whose heating systems were also being upgraded and connected to the heat network with funding from Scottish Government. While there are around 1,600 tenant-households (of whom we interviewed around 10 per cent), there are some 300 owners, most of whom live in their properties, and hence are owner-occupiers. Using a similar interview instrument, we compared tenants with owner-occupiers on the same estate to see whether housing tenure made a difference to people's experiences and attitudes.

A year or so later, in late 2013/early 2014, we re-interviewed tenants and owner-occupiers[9] once the new system had been running for a year, in order to compare experiences before and after. We replicated the questions as far as we could, and elaborated some of the key themes and issues, thereby extending the interview substantially. By treating the interviews longitudinally, we were able to compare the same respondent's responses on the two occasions.

In this chapter, we explore four themes: people's satisfaction, or lack of it, with housing and heating, and whether there is a connection between the two; the extent to which installing a new heating system made an appreciable difference to people's levels of comfort and warmth; what they paid for heating before and after the changeover, in the context of their household budgets; and the mechanisms they used to cope with cold, before and after the change. Taken together, we are able to assess understandings of 'home', well-being and affordable energy, specifically looking at the connection between heating systems and social and physical well-being. We ask whether affordable heating in and of itself can have a transformative effect, or whether we also need to focus on tackling issues of generic poverty, under-employment and social inequalities.

Heating the home

Prior to the upgrade, the houses were equipped with electric storage heaters, designed to heat up overnight, when demand for electricity is low, and to produce warmth during the day. One consequence of this is that houses were coldest in the evenings when they were most likely to be occupied. On the whole, the night storage heaters on the estate had not been upgraded since the 1960s. Such heaters were generally installed on a multi-rate meter, with differential daytime and overnight prices for electricity. The price charged overnight was lower than the standard tariff, but there was a correspondingly higher daytime and evening price. While virtually all of the tenanted houses had been equipped with storage heaters, they were rarely or never used in 40 per cent of cases where tenants relied on their own space heaters which used more expensive day-rate electricity, or simply went without heating at all. Owner-occupiers, who lived mainly in the maisonettes which also had been originally equipped with night storage heaters, were equally disinclined to use them, but relied more on electric space heaters which they provided for themselves. Among both tenants and owner-occupiers, satisfaction with their heating systems was low. Only 27 per cent of tenants, and 31 per cent of owner-occupiers, declared themselves 'satisfied' with the night storage heaters. Many had simply become used to an antiquated heating system, or had learned to adjust their daily life to accommodate its vagaries.

Both tenants and owner-occupiers derived considerable satisfaction from the houses themselves, considering it 'home', so negative feelings about heating were

TABLE 9.1 Comparison of resident satisfaction with housing at Times 1 and 2

% by row	*Very satisfied*	*Fairly satisfied*	*Neither*	*Fairly dissatisfied*	*Verydissatisfied*	*base*
Tenants T1	19	65	1	9	6	80
Tenants T2	41	44	6	6	2	80
Owners T1	72	15	3	8	3	39
Owners T2	59	36	0	5	0	39

TABLE 9.2 Comparison of resident satisfaction with heating at Times 1 and 2

% by row	*Very satisfied*	*Fairly satisfied*	*Neither*	*Fairly dissatisfied*	*Very dissatisfied*	*base*
Tenants T1	6	21	19	22	31	80
Tenants T2	38	33	11	9	9	80
Owners T1	8	30	13	23	26	39
Owners T2	67	28	0	3	3	39

rarely read across into housing. Over 80 per cent of residents at Time 1 expressed satisfaction with their houses (see Table 9.1), with owners in particular declaring themselves *'very satisfied'* (72 per cent, compared with only 19 per cent of tenants). Among tenants and owners we also found high levels of security attaching to housing even before the heating was replaced. Eighty per cent of tenants considered their house as a place where they felt safe; a similar proportion said that they felt at home there; and only a quarter said that their house was somewhere they wished to get away from. Feelings of personal security and attachment were even higher among owners: over 90 per cent felt safe at home; virtually everyone felt at home there; and only around a fifth said it was a place to escape from. We concluded, then, that even with the old electric heating there was a considerable investment in 'home'.

After installation of the new district heating, we asked both tenants and owners the same set of questions about house satisfaction, and we found that it was associated with comparable or even higher levels. The major change occurred among tenants, not so much in general levels of satisfaction, but in the proportion saying they were *'very satisfied'* with their houses which rose more than twofold. Unsurprisingly, among owners who already expressed high levels of satisfaction, the figures were comparable.

A much larger increase in satisfaction for both tenants and owners occurred in relation to the new district heating system. Whereas a majority of tenants had been dissatisfied with the electric heating, over 70 per cent were now satisfied. For owners, almost half had been dissatisfied, whereas almost all were now satisfied.

Residents on the estate, then, whether tenants or owner-occupiers, expressed high levels of house satisfaction throughout, but their satisfaction with heating has grown significantly. Indeed, post-installation, housing satisfaction has improved even further. Here is an estate which falls well within the official threshold of multiple deprivation in which there are high levels of attachment to 'home'. It confirms Kearns *et al.*'s comment made about housing in west-central Scotland that 'most people derive psycho-social benefits from the home, with no great divide along housing tenure lines between owners and renters' (Kearns *et al.* 2000: 406). The key point to make is that people are committed to their homes, and invest considerable attachment to them. For most people 'our residence is where we live, but our home is how we live' (Ginsburg, in Mallett 2004: 83).

What do people want from the new heating system?

Both before and after installation, we asked residents what was most important to them about the new heating. Before installation, tenants focused on a reduction in fuel bills (65 per cent) followed by improved comfort and warmth (56 per cent), and being able to control the heating better (37 per cent). After installation, the focus on cutting fuel bills had fallen (51 per cent), with 54 per cent wanting improved comfort and warmth, and 29 per cent better control of the heating. For most owners, the overwhelming focus (75 per cent) before and after installation was on having a warm house rather than lower fuel bills.

We also asked owners whether they thought that being connected to the district heating network would affect the financial value of their property: 73 per cent thought it would improve the financial value of their home, though only 36 per cent said that this was important to them. When we asked owners about the most and least important reason for connecting to district heating, improving the market value of the property did not feature prominently (only three said it was the most important reason for connecting). We also asked owners an open ended question about opting in to the system: *'So why did you decide to connect to the district heating network?'*; none of the owners reported that it was to improve the financial value of their house.

Does the new heating system deliver warmth?

Wyndford residents have a strong sense of the place as home, and this has been reinforced by the major investment in the new heating system. Does it actually work in terms of residents' perception of warmth? At Time 2 we asked whether the heating upgrade had made people's homes warmer, and the overwhelming majority (81 per cent of tenants and 90 per cent of owners) reported that it had.

We also asked residents how often their homes had been too cold, both for the winter period preceding the installation of new heating, as well as the one following it. We asked: *'Were there times your home was too cold last winter?'*, and compared their responses at Time 1 and Time 2. The turnaround was dramatic.

TABLE 9.3 Percentage of residents saying their home was warmer or colder with the new heating system

% by row	*A lot warmer*	*A little warmer*	*No change*	*A little colder*	*Much colder*	*base*
Tenants	63	18	12	7	0	76
Owners	87	3	8	3	0	39

TABLE 9.4 Percentage of residents saying they were cold at Times 1 and 2

% by row	*All of the time*	*Most of the time*	*Some of the time*	*A little of the time*	*No, never*	*base*
Tenants T1	29	24	24	15	9	80
Tenants T2	3	1	9	8	80	79
Owners T1	31	8	18	18	26	39
Owners T2	0	8	5	3	84	37

For both groups we see a transformation in their assessment of warmth, but especially among tenants, with a ninefold increase in the proportion who said they had *never* been cold in the previous winter. Furthermore, the proportions saying that cold housing was a *'serious'* problem for them fell to one-third of previous levels (from 42 per cent to 14 per cent). We can see the change more dramatically if we focus on how the *same* people respond at the two time-points rather than comparing the aggregates. Thus, among tenants who said that in the previous winter they had been cold all or most of time, 70 per cent now said that they had *never* been cold in the subsequent winter. If anything, the warmth 'gain' is higher among tenants than among owners, given that a higher proportion of the tenants had been cold at Time 1 than owners. Furthermore, the multi-storey flats were insulated as part of the upgrade, whereas the maisonettes where the majority of owners live were not. Decisions on insulation were largely conditioned by whether this was fundable under CESP.

Paying for energy

Given that residents' assessment is that they now live in warmer houses, are they paying more, less or about the same energy bills compared with before? This is a difficult calculation to make, reliant as it is on accurate data. What people spend on energy in a given period is determined by multiple factors including the amount of energy consumed (which varies seasonally), their tariffs, and any discounts or additional charges, including charges to clear debts which may have built up in a previous period. As far as possible we have based estimates of households' annual energy consumption and expenditure on data in energy bills or statements. For others, particularly households using constant-rate payment

TABLE 9.5 Household annual energy bills before and after installation of district heating and insulation upgrade (sd=standard deviation)

	Tenants T1	*Tenants T2*	*% change*	*Owners T1*	*Owners T2*	*% change*
Mean (sd)	£818 (£449)	£936 (£359)	+14%	£1,082 (£377)	£1,197 (£284)	+11%
Median	£731	£790	+8%	£1,082	£1,238	+14%
base	65	66		24	25	

Note: The base numbers for households at Times 1 and 2 are different because the estimate of household annual energy bills at Time 1 required an estimate of electricity consumption for non-heating purposes to extrapolate heating across the year, heating being so seasonally variable. Therefore we can only estimate Time 1 annual bills for households with data available at Time 2 and there are two households (one tenant and one owner) who were only able to provide information at Time 2.

TABLE 9.6 Household annual energy bills assuming Time 2 electricity prices at Time 1 (sd=standard deviation)

	Tenants T1	*Tenants T2*	*% change*	*Owners T1*	*Owners T2*	*% change*
Mean (sd)	£963 (£547)	£936 (£359)	-3%	£1,268 (£463)	£1,197 (£284)	-5%
Median	£863	£790	-8%	£1,123	£1,238	+10%
base	65	66		24	25	

meters, the data we were able to gather through the survey were a household's estimate of their expenditure in a given period. Using these data we have extrapolated to annual energy consumption and expenditure, correcting for seasonal variation, before and after installation:

These data (Table 9.5) indicate that, comparing like with like, both tenants and owners seem to be spending more on energy (heat and power combined) since installation of the new heating system and insulation. Such comparisons do not however take into account retail energy price increases since the new heating was installed; to do that we estimated what people would have paid if they had used the same amount of electricity at Time 1 but paid the higher Time 2 electricity tariff. This allowed us to compare what people pay after the heating upgrade with what they would have paid in the same year had the upgrade not taken place. With this calculation households tend to see a modest saving (Table 9.6).

These comparisons should be treated as indicative of the short-term impact of the new heating system. Some residents have struggled with the new heating controls (particularly programmer and thermostats), standing charges and billing arrangements, and debts run up with the new constant-rate payment meters (see below). For these households our estimate of annual expenditure is likely to overestimate long-term costs for two reasons: first, reported expenditure may cover both the cost of energy in that period plus an excess levied to clear debts accrued in a previous period; second, as households become more familiar with the system, they are likely to improve their control over consumption. Where we have not been able to inspect household bills, we were unable to identify the households to which the former issue applies.

One factor contributing to residents' difficulty in managing their heating costs is the lag between using the heating and impact on bills. The constant-rate payment meter system, introduced by SSE, charges a fixed weekly amount to the household based on estimated heat consumption averaged across a year. SSE review and revise charges quarterly in response to actual consumption, and seek to be proactive where customers may be running up debts. The intention of this approach is that, once bedded in, it should enable residents to spread their heating costs across the year, paying the same amount each week, and making budgeting for energy more straightforward. However, during the transition, a household which uses the heating a lot, or sets the wall thermostat to a high temperature (perhaps because they have not understood the controls, or because keeping the house very warm does not seem to impact on how much money the meter takes off each week), may unwittingly run up debts. This is because the impact of consumption being higher than SSE's estimate only becomes apparent to a household when their fixed charge is reviewed.

Part of the change in energy bills also results from changes in standing charges. Before installation of district heating, households paid a single electricity bill and standing charge; the new system added to this a second bill for heating including a standing charge for heat. From May 2013 tenants paid a fixed charge for heating, equivalent to £157 per year (including VAT) and owners paid £249 per year (see above). Electricity standing charges vary with different tariffs, with a median of £105 per year for both tenants and owners. While the variable costs of energy services should have fallen (due both to district heating and additional insulation), the fixed costs have risen. In this context we found that households with higher levels of consumption at Time 1 are more likely to save money than households with low consumption levels. A low heat user tariff has recently been introduced by SSE for households using less than 1,500kWh per annum. In 2014, this tariff was 9.33p/kWh (higher than the standard 5.62p/kWh, both inc. VAT), with a zero standing charge. A secondary qualifying criterion for acceptance onto the tariff follows the Warm Homes Discount matrix, and largely relates to recipients of welfare benefits. All households who meet the criteria have been invited by SSE to switch to the tariff, via two letters and an open day event in the local Community Centre; call centre staff are also trained to identify such households. In addition, Cube's home energy adviser is seeking out households likely to be eligible. Very few have so far transferred to the tariff.

Energy bills also vary with type of housing. Most tenants live in the multi-storey flats, while most owners live in the maisonettes; the multi-storey flats have had greater investment in insulation.[10] Thus, if we compare median bills,[11] the rate of increase has been greater for people living in the maisonettes than the multi-storey flats, and greater for owners than tenants.

There are also high correlations between what people pay at both time periods.[12] Looking more closely at the relationship between what people spend on heating and power at Time 1 and Time 2, with data on the subset of all households for whom we have reliable data (see Figure 9.1), we find the following:

- Most households are spending £500 to £1,000pa on energy before and after the new heating.
- The 'break even' line on Figure 9.1 indicates energy costs being equal at Times 1 and 2. Most households are above this line, reflecting the fact that in nominal terms most households are paying more with the new heating than they were before.
- The 'best fit' line on Figure 9.1 indicates the best-estimate linear relationship between bills at Time 1 and Time 2. The 'best fit' and 'break even' lines cross each other at a little over £1,000: while there is much variation, households paying more than £1,000 at Time 1 tend to make savings at Time 2, with mean bill reduction of £128. Conversely households paying less than £1,000 at Time 1 tend to face higher costs at Time 2, with mean bill increases of £232.
- The same point is illustrated by the fact that of the 18 households which spent less than £500pa at Time 1, none spent less than this amount at Time 2, 16 had seen bills rise to between £500 and £1,000 and 2 spent between £1,000 and £2,000.

Various complementary interpretations of these patterns are possible. Low users may have rationed their heating at Time 1, whereas they are now more willing to use it, even to the extent of paying more. High users, by contrast, were willing to pay to achieve warmer homes at Time 1, so the 'warmth gain' is less for this group. In addition, households are also now subject to both electricity and heating standing charges, which are higher in total than before. Some households also struggle to use the new heating controls and have lost the immediate feedback on energy costs in the transition from pre-pay electricity to the constant-rate payment meters described above. These may have used more energy than they would choose.

Figure 9.1 for household spending on energy at Times 1 and 2 also indicates the high level of variation in energy use between households living in broadly comparable dwellings. Notable contrasts include two tenant households who are high spenders on both occasions and two tenant households who were low spenders at Time 1 (less than £500pa) but high spenders at Time 2 (more than £1,500pa). There are also four tenant households who spent above £1,500pa at Time 1, but reduced spending at Time 2. The point is not that these households are deviating from a notional economically 'rational' average, but that consumption of energy has to be understood in the context of household routines and specific needs; this is reflected in the relatively loose fitting regression line, and a low R-squared.

Focusing on the owners, spending by most was between £500 and £1,000pa at Time 1, and £1,000–£1,500pa at Time 2, indicating that most are spending more on energy since the installation of new heating; relatively few spend less. Once

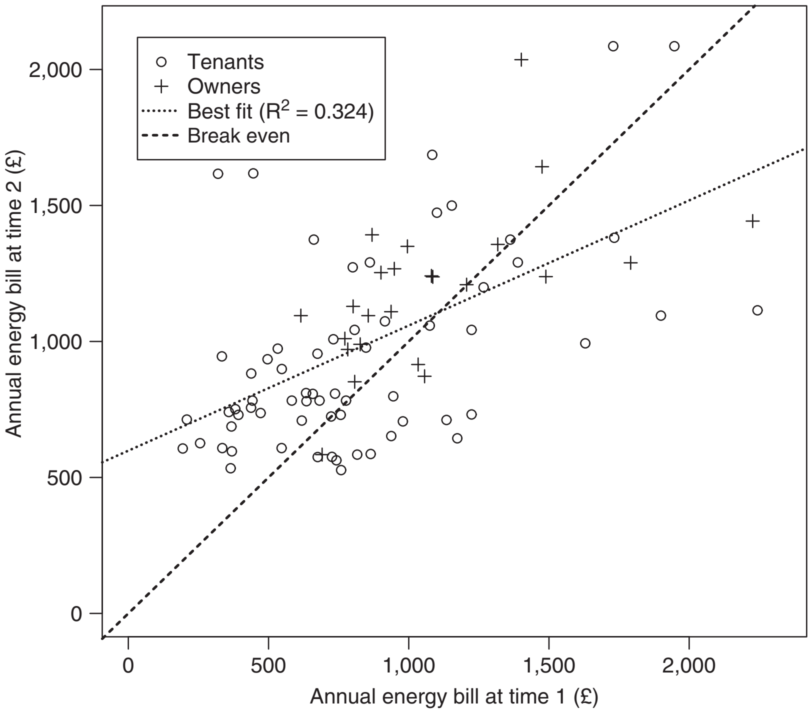

FIGURE 9.1 Comparison of estimated household energy bills per annum at Time 1 and Time 2.

more, there are high- and low-spend examples such as two households who are spending significantly more at Time 2 than Time 1, matched by another two spending considerably less.

Across our sample, there is a diversity of household heating practices and the variation in degrees of understanding and control. Thus, in two cases (A and B) where residents were relatively high spenders at both Times 1 and 2, they differed with regard to whether they understand the new heating. Case A, for example, spends 20 per cent more than previously, and reported that they did not understand how to control the heating. On the other hand, case B saves 35 per cent, and reported that they understood how to operate the system and are satisfied with it. B manages to save more than a third, while remaining a relatively high spender by choice, while A does not appear to manage either the old or the new system well. Two 'low spenders' at Times 1 and 2, C and D, appear to be highly organised and instrumental in their use of the heating system. Nevertheless, one (C) is paying three times what they spent previously, and commented that they have a *'better feeling of well-being with new heating'* and are happy now to be at home. Case D has reduced spending by 15 per cent and said they felt that they had the understanding and control required and thought they were paying about the same as before but were a lot warmer. There were also residents (E and F) who moved from being low to high spenders on energy. Both seem confused about the new heating system, and this was reflected in significantly higher spending, although respondent F was the better off, and felt that they had not had to cut back spending on anything else to manage the increased energy costs. Finally, there were households such as G and H who moved from being high spenders to low spenders, saving, respectively, 40 per cent and 28 per cent on energy bills. Both seemed to be efficient users of the new heating, setting the programme timer and using the radiator thermostatic valves.

There is then no simple story behind how domestic consumers use energy. Some are high users before and after installation; others are low users on both occasions; while some move from being high to low users, and others from being low to high users. The key lies in how energy use fits into their overall lives and day-to-day practices.

We conclude that *as a group* Wyndford households are paying roughly the same for energy services had they continued using electric heating (with rising electricity prices), but they have experienced significant improvements in levels of warmth. The fact that overall energy costs have stayed much the same is true in relative as well as absolute terms, as reflected in the fact that few owners or tenants report a significant fall in the proportion of household income spent on energy. Disaggregating, we find households whose energy consumption before the upgrade was high have seen absolute savings in their bills, while lower consumption households tend to have higher bills with the new system. The overwhelming majority of households report that the changes have resulted in considerably warmer homes and a dramatic fall in the frequency of periods when their homes are too cold (in most cases to '*never*').

People's expectations at Time 1 of what they would end up paying for the new heating displayed ambivalence or even scepticism as to whether savings would be made. Thus, we found that 41 per cent of tenants, and 38 per cent of owners, expected that they would *'end up paying more'*, and only 32 per cent of tenants and 24 per cent of owners thought that they would pay less.[13] When we returned at Time 2, those tenants who considered they were now paying less for their energy mostly thought that any savings would simply go on *'just getting by'* or on buying more food. Similarly, among tenants who thought they were paying more for energy, cutting back on food was the most common response to increased energy bills.

Coping with cold houses and the effects of the new district heating

We now focus on how Wyndford residents coped with cold houses at Time 1, and whether there has been a significant change in the mechanisms they use to cope. Keeping warm at home in a cold climate like Scotland's, when housing energy efficiency standards have historically been poor, presents challenges. The pan-Scottish survey, carried out between 2002 and 2006, of 1,281 households who

TABLE 9.7 Percentage reporting use of various coping mechanisms or experiences of cold after new heating had been installed (pre-installation responses in brackets)

% mentioning	*Tenants*	*Owners*	*Scottish Central Heating Programme study*
Wore outdoor clothing indoors to keep warm	25 (66)	9 (28)	26
Turned off heating in some rooms	23 (49)	34 (32)	21
Not move from room to room because of the cold	16 (48)	9 (36)	27
Turned heating down in some rooms	26 (42)	31 (34)	21
Gone to bed early in order to be warm	17 (42)	6 (32)	19
Found yourself shivering with cold when sitting still	16 (40)	3 (42)	21
Turned off heating for few days	17 (39)	12 (12)	8
Gone somewhere else to stay warm	9 (35)	3 (10)	N/A
Borrowed money for heating	14 (34)	3 (4)	8
Cut back on social or leisure activities	21 (44)	3 (16)	12
Cut back on food expenditure	14 (27)	9 (10)	9
Put off paying other important bills	17 (27)	3 (6)	9
Avoid going outside as too hard to get warm upon re-entry	5 (26)	3 (22)	13

Note: The question respondents were asked was *'Thinking back to last winter, did you do any of these things to help you pay for heating?'*

received central heating under the Scottish Government-funded Central Heating Programme (Scottish Executive Social Research 2007) examined coping mechanisms which respondents used to help keep warm and pay for their heating. These provide a useful benchmark against which we are able to compare responses in our surveys of Wyndford pre- and post-installation of new heating. The reported improvements at Wyndford are dramatic.

The findings show significant reduction, especially among tenants, in the proportion of residents who struggled to keep warm. There is now greater use of 'conventional', less drastic, measures used by many residents to control heating costs, such as turning the heating down or off in some rooms, not moving from room to room, putting on warm clothing, and sometimes *'shivering'*. While at Time 1 Wyndford residents were far more likely to use all of the coping mechanisms than the Scottish Central Heating Programme sample, by Time 2, they were more in line with the national sample.

What of people's use of combinations of different mechanisms? At Time 1, only 4 per cent of tenants used all the mechanisms, but 13 per cent used all three of the more serious ones: cutting back spending on food, borrowing money or running up debts, and deferring paying other bills. After the installation of the new heating system, only four per cent of tenants used these three 'serious' mechanisms, and none used all the mechanisms.[14] Virtually no owners, on the other hand, used the serious mechanisms either at Time 1 or Time 2.[15]

With the old electric heating, being young, unemployed, and living in the multi-storey flats resulted in a greater propensity to defer paying other important non-energy bills. After installation, however, it is those who are unemployed who experience most difficulty, and new heating has eased the difficulties faced by younger people and people living in multi-storey flats.

Conclusion

What are the implications of this study for the broader questions of this book, namely, the prospects for sustainable energy for heating, where 'sustainable' means low carbon, affordable for users and secure over the longer term? The chapter provides evidence about the affordability of the new community heating system which was also designed to be more efficient and carbon-saving. A focus on techno-economic processes however is not sufficient in and of itself. We see from our study that the diversity of people's responses to the new system, to its costs, and how they use it in the context of their lives, indicate that creating sustainable, affordable heating provision is not simply a techno-economic exercise. It requires careful work with householders so that they can maintain a sense of control over their use of energy, and what they are paying.

There is also a broader question: can affordable heating itself have a transformative effect on people's lives and well-being, or do we also need to concentrate on tackling issues of generic poverty, of under-employment and social inequalities? As we have seen, most people end up paying slightly less than they would have under the old system, but have the benefit of living in far warmer houses. In that regard, the quality of their lives, and potentially their health and life chances, have modestly improved. Thus, residents say they are warmer, that they have less recourse to coping strategies to stay warm, and that their general sense of well-being and housing satisfaction have improved.

Nevertheless, people's non-energy finances remain much as they did before, in an estate which falls within the 10 per cent most deprived in Scotland. Recent changes (overwhelmingly reductions) in UK welfare programmes and stagnating real incomes add further pressures to what are already low incomes. With the new system it should be possible for a household on the Wyndford estate to regulate its heat consumption downwards in response to these pressures to save money, without necessarily suffering the levels of cold they experienced before the heating system was installed. Nevertheless, the room for manoeuvre is restricted, because the minimum combined energy bill is higher than it used to be, as it now comprises two standing charges. Put at its simplest, it is no longer possible to turn off the heating altogether and pay nothing. Under modest financial pressures, then, a household may be better able to cope because it can turn the heating down a bit and not suffer too much cold, but cannot dispense with heating, and its costs, entirely. Because heating tariffs are index-linked to prevailing energy prices over the longer term, this may simply be a modest but welcome diversion from the broader effects of mounting economic pressures on poor households. Technological interventions may only do so much in the face of structured social inequalities which are driven by wider economic, political and social forces.

Notes

1 www.citizensadvice.org.uk/index/pressoffice/press_index/press_20131117.htm.
2 'Housing, fuel and power' includes rent, fuel, electricity and maintenance and excludes mortgages and council tax. See ONS (2014).
3 The measure of fuel poverty reviewed by Hills categorised a household as fuel poor if it would need to spend 10 per cent or more of its income on fuel to achieve a standardised heating regime. The revised measure proposed by Hills categorised a household as fuel poor if two conditions were met: the household's required fuel costs were above the national median, and if they were to spend that amount they would be left with a residual income below the official poverty line (Hills 2012).
4 In the system of government in the UK since 1999, energy regulation and taxation are the responsibility of UK Government, while the devolved Scottish Government is responsible for housing, planning and the promotion of energy efficiency, and can promote energy technology innovation. District heating, lying outside the responsibility of the energy regulator and not mentioned in the devolution legislation, is regarded as devolved 'by omission' to the Scottish Government.
5 As measured by the Scottish Government's Index of Multiple Deprivation (simd.scotland.gov.uk/publication-2012/).
6 Scottish Homes was the successor body to the government agency, the Scottish Special Housing Association (SSHA) which was set up in the 1930s by the UK Government to provide good quality public housing in Scotland. SSHA built the estate described in the paper in the 1960s on the site of the former army barracks at Wyndford. The estate won a design award in 1968. It is three miles from the city centre in the Maryhill district of north Glasgow.
7 Maisonettes are flats on two levels with internal stairs, or which have their own entrance at street level. They were common forms of urban housing built during the 1960s and 1970s as they were easy and cheap to construct in a short period of time. They were, as on this estate, built in a row to form a terrace of maisonettes, with upper and lower apartments. The term 'walk up' refers to the absence of lifts, present in all other buildings on the estate for reaching flat entrances above ground level.
8 Two of these were sublet to Glasgow City Council which has a letting arrangement with the housing association.
9 We interviewed 80 of the 154 tenants, and 39 of the 50 owner-occupiers. Those we were unable to trace were marginally more likely to live in multi-storey flats, to have lived less time on the estate, and to be somewhat younger. Nevertheless, those interviewed and not interviewed were broadly similar in terms of social characteristics and attitudes.
10 Work is still on-going on the estate providing insulation to the remaining properties.
11 As reflected in the size of the standard deviations about the mean, there is considerable inter-personal variation, especially among tenants, so we have focused here on the median bills.
12 For tenants, $r=0.524$ ($p<.001$); and for owners, $r=0.564$ ($p=.004$).
13 21 per cent of tenants, and 30 per cent of owners thought they would end up paying *'about the same'* as before.

14 It might seem anomalous that fewer use coping mechanisms when the median spending on energy has risen. The median is what the 'middle person' in the sample spends, and is less susceptible than the mean to extreme variations around the mean, which are considerable.

15 On each occasion, only a single owner (though this was a different respondent at Time 1 and Time 2) did so.

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10

THE SURPRISING OUTCOMES OF UK ENERGY AND CLIMATE POLICY

Zero carbon housing targets and the emerging opportunities for district heating

Heather Lovell

The chapter draws on the case of the English 2016 zero carbon homes policy to illustrate the uncertain and fluctuating degree of policy support for heat in UK policy. Building on analysis of UK heat policy in previous chapters, it demonstrates how a significant opportunity for district heating has arisen from an unexpected direction – housing policy and building regulations – with estimated financial support of up to £200m per year (Combined Heat and Power Association [CHPA] 2011). It explores how this opportunity – termed 'allowable solutions' – has arisen in a largely unplanned and haphazard way, giving a detailed example of the issues discussed particularly in Chapter 5.

Introduction

This chapter is about the stringent target in England for all new housing to be 'zero carbon' by the year 2016. This target was set by the UK Government back in 2006, thereby giving the housebuilding industry ten years in which to prepare. Much of the debate about the zero carbon target in the intervening period has focused on the precise definition of 'zero carbon'. Its interpretative flexibility (Pinch and Bijker 1984) has not been firmed up, and remains contested. At the outset in 2006 when the policy was first developed 'zero carbon' was taken to mean no net emissions[1] of carbon from each home (equivalent to the UK voluntary Code for Sustainable Homes – Level 6). Over time, with mounting industry protests about the costs and technical feasibility of reaching this zero carbon standard for all new homes, the zero carbon definition has been extended to include climate mitigation measures implemented off-site – i.e. beyond or outwith the new housing development – through so-called 'allowable solutions' (Zero Carbon Hub 2012; Department of Energy and Climate Change [DECC] 2013). The evolution of the zero carbon homes target in this direction has given an unexpected and significant boost to district heating, because district heating has been identified as one of the most promising 'allowable solutions' (Zero Carbon Hub 2012, 2013; CHPA 2014). First, the analysis shows how housing policy is an important avenue of government support for heat, as well as energy policy (see also chapters 5 and 6). Second, the zero carbon homes case study reveals a surprising irony: it is likely that because of the absence of a coherent policy and investment framework for heat that district heating will become eligible for funding under the zero carbon homes policy. This is because of the complex 'additionality' rules associated with allowable solutions, meaning that low carbon technologies which already receive funding and policy support cannot be supported as an allowable solution (this would be 'double counting').

The overall objective of the chapter is to illustrate how policy support for domestic heat and district heating in the UK continues to be complex and uncertain, using the case of the English Zero Carbon Homes (ZCH) policy. The chapter demonstrates some of the difficulties of effecting systemic shifts in infrastructures such as housing and energy in response to the problem of climate change. As argued in chapters 2 and 5, privatised and liberalised energy systems – where market-based forms of operation and governance dominate – can have significant limiting impacts on sustainable energy policy. Further, the case of zero carbon homes and district heating illustrates well the degree of complexity arising from neo-liberal, market-based infrastructures. In practice, the promised ideal type of a free market with 'government at a distance' has not materialised.

The details of how and why the zero carbon homes policy has evolved since its inception in 2006 are covered in the section below. The chapter then goes on to discuss in detail what the shifts in the ZCH policy mean for district heating, and in particular how the uncertain and patchy policy and investment support for district heating acts in its favour with respect to 'allowable solutions'. Essentially a type of offsetting, allowable solutions will enable housebuilders to generate greenhouse gas emission reductions 'offsite' from a new housing development, in order to comply with the zero carbon target (Green Building Council 2008). District heating is being positioned by several key organisations – the Zero Carbon Hub, the UK Green Building Council, the UK Association for Decentralised Energy (formerly named the Combined Heat and Power Association, here referred to as CHPA) – as one of the leading eligible technologies for allowable solutions (CHPA 2011; Zero Carbon Hub 2012, 2013).

Before proceeding a few key issues are clarified, as follows. First, the ZCH policy is applicable to England only, not the UK as a whole. This is because housing policy and building regulations are devolved issues, i.e. set independently by the devolved administrations of Scotland, Northern Ireland and Wales. This chapter focuses on England. However, it seems likely that allowable solutions will actually be able to be implemented UK-wide, i.e. that allowable solutions to English zero carbon homes could be located outside of England (Department for Communities and Local Government [DCLG] 2013). A variation on the English 'allowable solutions' is also being considered for Scottish building regulations (Sullivan 2013).

Second, at the time of writing (mid 2014) ZCH policy is still in the process of being finalised and several key details about the ZCH have not yet been agreed (see DCLG 2014).

The chapter is based on empirical research undertaken during the first half of 2014. It comprises desk-based research, primarily a review and coding of key documents related to the ZCH policy, including all documents on ZCH published by: UK Government departments; the Zero Carbon Hub, a public-private organisation established in 2008 specifically to lead discussions on and help with implementation of the 2016 ZCH target; the UK Green Building Council (GBC), an independent organisation working to encourage zero carbon homes; and the UK CHPA.

The twists and turns of the ZCH policy (2006–14)

The details of the English ZCH policy have yet to be finalised, despite several years of negotiation. Indeed, a key feature of this policy debate has been its prolonged and protracted nature. The gradual shifts over time in the original policy have acted to considerably reduce its stringency. And, whilst there has been much discontent amongst green groups and environmental building lobbyists about the watering down of the zero carbon homes target, for district heating the shifts may potentially (and surprisingly) result in significant financial support.

It was in the UK Government's 2006 *Building a Greener Future: towards zero carbon development* consultation document that the Housing Minister Ruth Kelly announced that 'Our key goal is to achieve zero carbon new homes within a decade' (DCLG 2006: 1). Even at this early stage of planning care was taken to specify what was meant by a zero carbon home, with an ambition to address emissions from *all* domestic energy consumption, as follows:

> For a new home to be genuinely zero carbon it will need to deliver zero carbon (net over the year) for all energy use in the home – cooking, washing and electronic entertainment appliances as well as space heating, cooling, ventilation, lighting and hot water … it could be at the development or building level.
>
> *(DCLG 2006: 15)*

This first definition of a zero carbon home hinted that district heating might be supported, with its mention of 'development level' boundaries. The government also set out in *Building for a Greener Future* the three main ways the zero carbon target would be achieved: through the planning system, the building regulations (via 'Part L', which relates to energy), and a voluntary sustainable building standard – the Code for Sustainable Homes. Interim steps for upgrading Part L of the Building Standards were proposed: a 25 per cent improvement on energy use on current building regulations by 2010 and a 44 per cent improvement by 2013. In *Building* *for a Greener Future* the government was confident about its zero carbon target, stressing both the need for such an ambitious target and the likelihood of achieving it. For example, Housing Minister Ruth Kelly said in her speech launching the consultation that

> It is vital that homes and other buildings are as sustainable and as eco-friendly as possible … within a decade I want every new home to be zero-carbon … This country is the first to set this ambition and we look forward to our international partners matching it.[2]
>
> *(Kelly 2006)*

It was not long, however, before the government ran into problems regarding its definition of a zero carbon home, giving an early indication of the numerous alterations to the definition that were to follow. In March 2007 Her Majesty's Revenue and Customs (HMRC) published Budget Note 26, a seemingly innocuous briefing about the forthcoming Stamp Duty Land Tax (property tax) exemption for zero carbon homes (HMRC 2007). It caused a stir though in housebuilding professional circles because its definition of zero carbon excluded off-site renewables, stating that zero carbon homes could only be credited with emissions reductions from 'off-site renewables if a private wire connection was in place' (HMRC 2007). This treatment of off-site renewables was inconsistent with the definition of zero carbon then in use within the voluntary standard Code for Sustainable Homes, which allowed off-site renewables to contribute to the standard even if not physically connected to the building. The Code for Sustainable Homes definition was subsequently adjusted to be in line with Budget Note 26. Excluding the offsetting impact of off-site renewables from a zero carbon home's net emissions made the target significantly more stringent, which the housebuilding industry regarded as problematic and objected to. To resolve this initial dispute the UK Government asked the respected Green Building Council – a non-profit consultancy, with membership from across the building industry – to investigate the definition of a zero carbon home and give advice about how to proceed. Their 40 page report, entitled simply *The Definition of Zero Carbon* recommended a revised definition of a zero carbon home 'that allows the use of off-site solutions in certain circumstances' (Green Building Council 2008: 5). These 'off-site solutions' were soon to become widely referred to as 'allowable solutions'.

Struggles over the zero carbon home definition continued over the next several years: it has been a prolonged series of seemingly small changes and modifications to definitions which have been interpreted by various groups as having major consequences for the cost and carbon impacts of the policy. Changes have been made to accommodate different interests, as well as the changing economic context (notably the 2007–09 recession). There is not the space, however, to delve into all these twists and turns in this short chapter. The timeline in Box 10.1 summarises the main decisions in the period 2006–14. Two issues are important to draw out in terms of their relevance for district heating, discussed in turn below: first, the emergence in 2008 – and the subsequent refinement – of the term 'allowable solutions'; and, second, the significant change in the stringency of the ZCH target in early 2011, which means considerably less funding will be available for district heating and other low carbon technologies eligible for allowable solutions.

BOX 10.1 THE UK ZERO CARBON HOMES POLICY TIMELINE

In 2006 Ruth Kelly MP, Minister for Communities and Local Government, announces the Government's intention that all new build homes will be zero carbon from 2016 (simultaneously launching the holistic Code for Sustainable Homes, the highest level of which enshrines the zero carbon standard).

Subsequently the '2016 Zero Carbon Task Force' is convened, co-chaired by the Housing Minster and Chief Executive of the Home Builders Federation. The Task Force assigns a group of experts, under the auspices of the UK Green Building Council, to undertake a detailed assessment of the definition of zero carbon homes and provide recommendations.

In May 2008 the Zero Carbon Task Group reports back recommending a hierarchical approach starting with energy efficiency first, followed by carbon compliance (largely onsite) and allowable solutions (largely offsite).

In June 2008 the Zero Carbon Hub is launched with a mandate from Government to take day-to-day operational responsibility for coordinating delivery of low and zero carbon new homes reporting directly into the 2016 Zero Carbon Task Force.

In December 2008 Government launches a consultation on the definition of 'Zero Carbon Homes' based on recommendations from the task group in May.

In July 2009 the Housing Minister announces that the Carbon Compliance level will be set at 70 per cent and tasks a specialist group to investigate the minimum energy efficiency standard for new build homes. The Carbon Compliance level specifies how much of the carbon emissions must be dealt with on-site (i.e. by energy efficiency and/or on-site renewables), and so the remaining emissions (30 per cent) are potential off-site 'allowable solutions'.

March 2011 – Budget announcement by Government that zero carbon homes will no longer take into account unregulated energy use within the home. Only energy covered by building regulations (predominantly heating and lighting) will be included in the target, other energy consumption (e.g. for electrical appliances) will be excluded.

In August 2013 the Government launches a consultation specifically about the allowable solutions part of its ZCH policy: 'Next steps to zero carbon homes – allowable solutions'.

In June 2014 in the Queen's Speech allowable solutions were confirmed as a component of the ZCH policy, within the Infrastructure Bill.

Source acknowledgement: Adapted from WWF-UK (2011b: 6).

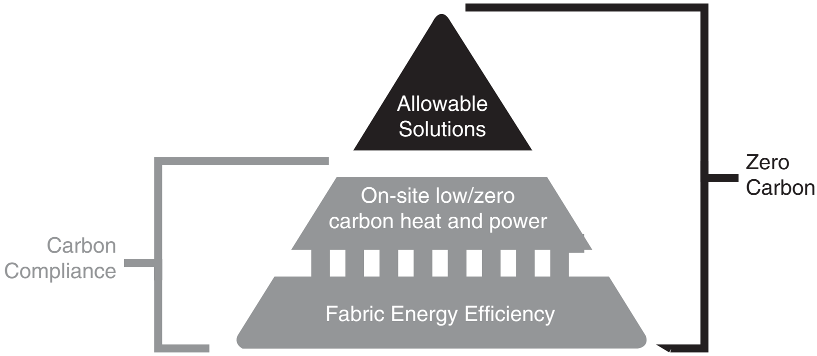

FIGURE 10.1 'Stepped approach' to achieving a ZCH standard. Source: Courtesy of Zero Carbon Hub (2014: 4).

The term 'allowable solutions' was first mentioned in the 2008 Green Building Council Report, and then defined more clearly in relation to ZCH in a later government consultation document as 'a range of solutions … that can deal with the emissions that cannot be dealt with on the site of the development' (DCLG 2008: 25; see Figure 10.1). Allowable solutions emerged as a direct response to the objections raised by the housebuilding industry regarding the financial cost and technical feasibility of achieving all carbon reductions within the building envelope of the home itself (Green Building Council 2008).

In the period since 2008 there has been on-going (and still unresolved) debate about what allowable solutions might be, and the practicalities of how they might work. In August 2013 the government launched a consultation specifically about the allowable solutions part of its ZCH policy 'Next steps to zero carbon homes – allowable solutions' (DCLG 2013). Examples of questions raised in this consultation document include whether to set a 'prescribed list' of low carbon technologies that can be used as an allowable solution, or to use a more flexible criteria-based approach (e.g. an amount of carbon savings per kWh energy consumed), how to administer and verify allowable solutions, as well as issues of additionality (i.e. making sure that allowable solution technologies were not going to be put in place anyhow), the role of local authorities in administering allowable solutions vis-à-vis national-level private sector funds, and possible overlap with the European emissions trading scheme (DCLG 2013). Just under two hundred responses (#172) were received by the 2013 Allowable Solutions' Consultation, the results of which were announced in July 2014 (DCLG 2014). Respondents were mostly from local authorities (32 per cent) with housebuilders only comprising 15 per cent. In June 2014 allowable solutions were finally confirmed as a definite part of the ZCH policy (see Box 10.2), with the legislative amendments required to facilitate this proposed within the Queen's Speech.[3] However, this announcement and the consultation process in effect did little to finalise what ZCH allowable solutions are, or how they can be used, with key issues such as the type of technologies to be included, and the allowable solutions price cap[4] left open (DCLG 2014: 6–7).

BOX 10.2 GOVERNMENT GUIDANCE ON THE QUEENS SPEECH 2014 – SECTION 3.8 'NEW HOMES BUILT TO A ZERO CARBON STANDARD'

The government is committed to implementing a zero carbon standard for new homes from 2016. But it is not always technically feasible or cost effective for housebuilders to mitigate all emissions on-site.

The government would set a minimum energy performance standard through the building regulations. The remainder of the zero carbon target can be met through cost effective off-site carbon abatement measures – known as 'allowable solutions'. These provide an optional, cost-effective and flexible means for housebuilders to meet the zero carbon homes standard, as an alternative to increased on-site energy efficiency measures or renewable energy (such as solar panels). Small sites, which are most commonly developed by small scale house builders, will be exempt. The definition of a small site will be consulted on shortly, and set out in regulation.

The Zero Carbon Home standard will be set at Level 5 of the Code for Sustainable Homes, but the legislation will allow developers to build to Level 4 as long as they offset through the allowable solutions scheme to achieve Code 5.

Energy efficiency requirements for homes are set out in the Building Regulations 2010 and are made under powers in the Building Act 1984. But there are insufficient powers in the Building Act to introduce off-site allowable solutions, so the government will now bring forward enabling powers for this.

Source: UK Government Cabinet Office (2014).

A second key development in the ZCH policy since its inception in 2006 was a decision made in the March 2011 Budget. Hidden in a footnote in the Budget, and expanded on in an accompanying document *The Plan for Growth*, was a significant alteration of the definition of zero carbon, effectively reducing its stringency by one third, arguing this was necessary 'to ensure that it remains viable to build new houses' (UK Treasury and Department for Business Innovation and Skills [BIS] 2011: 117). The change was that cooking and plug-in electrical appliances (ovens, computers, fridges and so on), so called 'unregulated energy use' (i.e. not covered by the Building Regulations) would be excluded from the definition. The ZCH definition henceforth includes only 'regulated energy'. This is the energy used to provide space heating and cooling, hot water and fixed lighting. There was a fierce reaction to the change in definition, with the environmental NGO WWF-UK, for example, resigning from the zero carbon home taskforce in protest. In their resignation letter to the Housing Minister, WWF-UK stated that: 'the alteration to this policy is a fundamental one which significantly undermines the original intent of this policy – for new homes to add zero net carbon emissions' (WWF-UK 2011a). UK Green Building Council chief executive Paul King commented 'A zero carbon home will no longer do what it says on the tin' (Nichols 2011). The net effect of this reduction in the ZCH target is that less funding will be available under 'allowable solutions', because more can be done within the building envelope to meet the (now lower) carbon emissions targets.

District heating and the shifting nature of the ZCH policy

Here we now turn to consider the relationship between ZCH and district heating. The ZCH policy is a form of support for district heating in the UK that stems not from the energy policy sector (see chapters 4 and 5), but rather from within housing policy. Housing and building regulations sit within a different government department (the Department for Communities and Local Government) to energy (and heat) policy (the Department for Energy and Climate Change) and this institutional divide is one likely reason why progress to implementation of the ZCH policy has been so slow.

At the time of writing (mid-2014) there has been no definite decision about whether district heating will be included in the ZCH policy as a type of allowable solution (CHPA 2014). However, it is being positioned as a promising option (CHPA 2011; Zero Carbon Hub 2012: 23–24). For example, a report by the Zero Carbon Hub on allowable solutions commends district heating because 'customers can understand it as a solution' and further that 'district heating [is] a mature technology where the costs are known and installation is a straightforward civil engineering project' (Zero Carbon Hub 2012: 24).

In 2011 the UK Combined Heat and Power Association (CHPA) was invited by the UK government to 'make the case for district heating networks to receive support from Allowable Solutions' (CHPA 2011: 3). The resulting CHPA report *Energy and Carbon Savings – Using Allowable Solutions with district heating to fill the gaps in Government policy* proposed that a 25 per cent capital contribution to district heating schemes from allowable solutions – equal to as much as £200 million per annum – would 'fill the policy gap' (CHPA 2011: 3), enabling significantly more district heating to be implemented across the UK. However, the report also stressed the need for certainty in order to facilitate planning for district heating, noting that 'To secure investment, the Government needs to make an announcement as soon as possible that district heating will be eligible for funding under Allowable Solutions' (CHPA 2011: 13). It is telling that three years later such a decision has yet to be announced. Thus, as with the various policies discussed in Chapter 5, 'market players' are afforded little insight into whether policy will support heat networks, or indeed what amount of support might be forthcoming. While some enterprising local authorities may seek to develop potential schemes to absorb allowable solutions funds, their capacity to coordinate multiple organisations around such uncertain prospects is limited. Policy uncertainty, then, is likely to result in relatively small heat networks being available to housebuilders as solutions to meeting the zero carbon standards, with consequently high costs relative to their impact, as compared with larger, more complex systems (see Chapter 5).

However, in spite of these uncertainties, and in an ironic twist of fate, district heating looks to be a key technology that could well receive funding under allowable solutions. This curious situation comes about because ZCH allowable solutions – as a type of offsetting – is required to provide 'additional' carbon savings, over and above what would be considered to happen anyhow. The concept of additionality is one that is central to all forms of offsetting, and has been most fully developed to date within the UN Clean Development Mechanism (CDM). Indeed, CDM experts have been included in discussion about allowable solutions, in order to learn lessons from how the CDM evolved, and what worked and what did not (Zero Carbon Hub 2012). The DCLG 2013 Consultation on allowable solutions outlines additionality as one of its five core 'design principles' of allowable solutions: 'The *carbon savings deriving from Allowable Solutions should be additional* and over and above the carbon savings that would have been delivered without the availability of Allowable Solutions' (DCLG 2013: 16, emphasis in original).

Thus a CHPA 2011 report remarked: 'Over the long-term (by 2050), district heating is expected by Government to deliver a major proportion of heating to residential and commercial properties. *There is presently no policy framework to drive this expansion*' (CHPA 2011; emphasis added). With a Heat Strategy (DECC 2013) now in place, the validity of these arguments around policy additionality have become less certain. However, DCLG constructs additionality as a multi-dimensional property, and agreement around other types of additionality – financial or market additionality – appears to be firming up. A Zero Carbon Hub report of a dedicated multi-stakeholder workshop on additionality concluded, for example, that:

> what clearly emerged was a consensus around the need to … consider a financial basis for a workable definition of additionality for Allowable Solutions. Therefore, in practice an option's additionality is judged by the 'funding gap' filled by Allowable Solutions in order to tip the viability of a sponsored project.
> *(Zero Carbon Hub 2012: 30)*

In the government's response to its 2013 consultation on allowable solutions – *Next steps to zero carbon homes – Allowable Solutions* (DCLG 2013, 2014), the consultation showed support for allowable solutions projects having:

> Complementarity: projects or measures counted as Allowable Solutions would complement but not displace projects supported separately by other government programmes, this is to avoid double subsidy [and] …

> Market Additionality: projects or measures would be those which would not otherwise have been brought forward by the market because of delivery barriers.
>
> *(DCLG 2014: 35)*

In this context, district heating is argued to be in a better position, rather ironically, than other low carbon technologies regarding its suitability for allowable solutions funding (CHPA 2011; Zero Carbon Hub 2012), because of its uncertain and variable policy support and funding sources. For instance, district heating forms one of two detailed case studies in a 2013 Zero Carbon Hub report providing guidance on how to achieve a zero carbon home (Zero Carbon Hub 2013).

Summary and conclusions

This chapter is about an English zero carbon housing policy that is being positioned to offer significant financial support to UK district heating. It is a case study that illustrates well the uncertain and changeable nature of policy support for heat in the UK discussed in Chapter 5. In spite of early articulation of the policy by government in order to give housebuilders a decade to prepare for compliance, this period has seen repeated and contentious revisions to the very definition of 'zero carbon'. Alongside the resulting uncertainty, however, and in an ironic twist, the analysis suggests it is precisely because of the *lack* of comprehensive policy and investment support for district heating that the technology is able to be positioned as a front-runner for allowable solutions funding. This is because it makes almost any heat network that is supported clearly 'additional' by the Government's criteria. Allowable solutions is a flexible carbon offsetting mechanism, and additionality is a key feature of such schemes. The mechanism has evolved over time through the contestation between different interpretations of what constitutes a 'net zero carbon emissions' new home to become a key component of the ZCH policy.

The case study is illustrative of a wider set of questions about how significant ('radical' after Hughes 1983) change in existing long-standing infrastructure systems may be effected. These debates have intensified as infrastructure systems have been privatised and liberalised (see Chapter 2), leading to a proliferation of market-based forms of governance, and a shift away from infrastructure planning. The resulting neo-liberalised infrastructures present significant challenges to those wishing to respond to big (long-term, large scale) problems such as climate change. Protracted debates, such as have occurred around ZCH and allowable solutions, cause uncertainty for the very 'market players' they are intended to suit, and provoke distrust amongst environmental NGOs and other lobbying for environmental sustainability. As we argue in Chapter 2 such intense politics around infrastructure transitions is nothing new, but rather an integral feature of *socio*-technical systems.

Notes

* In July 2015 (after this book went to press) the new Conservative government in the UK abolished the zero carbon homes policy, including allowable solutions. It is a further, final illustration of the instability of the zero carbon homes policy.

1 The zero carbon homes target does not include embodied carbon, i.e. carbon emissions associated with the building materials and appliances used in the home; see DCLG (2006).

2 This has happened in some cases in the intervening period. For example, the European Union has now in place a second, more stringent Energy Performance of Buildings Directive Directive (2010/31/EU), which replaces the original 2002 Directive, and stipulates targets for 'nearly zero-energy buildings' in the domestic and non-domestic sectors, namely that 'by 31 December 2020 all new buildings shall be nearly zero-energy consumption buildings' (see europa.eu/legislation_summaries/internal_market/single_market_for_goods/construction/en0021_en.htm).

3 At the opening of each session of UK parliament, the Monarch reads aloud a document setting out the UK Government's priorities for the coming year.

4 A wide band of possible carbon prices was proposed in the 2013 consultation document, ranging from £36 to £90 per tonne of carbon.

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PART V
Conclusion

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11

SOLUTIONS? CITIES AND CARBON INNOVATION

Coordination for sustainable heat

During the course of writing this book, the gas boilers in countless buildings in cities around Europe have continued to fire, providing heating and hot water in accord with the daily and seasonal rhythms of societies, the technical infrastructures of gas supply, and the economic and political infrastructures of supply chains, markets and regulation. Over this period most gas networks will have changed very little, either in their physical configuration, the rules governing their operation, or the organisations owning and managing them. That stability underpins the complex dynamics of energy flow: for example, households rely on these massive networks of pipes, allowing them to take for granted that they will be able to heat their homes; companies extracting gas from subterranean fields rely on both the physical infrastructures and market rules staying in place to enable them to sell their product. The socio-technical infrastructures of heating systems in many cities create complex interdependencies, and thereby lock in a significant contribution to continuing increases in atmospheric greenhouse gas concentrations and climate disruption. Their very ordinariness and centrality to urban societies are correlates of their obduracy, demonstrating the extraordinary demands entailed in their transformation.

Seen from this perspective heating in cities appears static. From another perspective, however, heating in cities and the infrastructures underpinning it are undergoing massive changes. In some respects the global environmental problems associated with urban heat demand appear to be worsening: urbanisation continues across the planet, with China the most notable contemporary example where the rapid construction and expansion of cities is accompanied by accelerating fossil fuel exploitation and environmental damage (Watts 2010). But in other respects changes point toward sustainable future cities and sustainable futures for existing cities, with a growing abundance of visionary statements foreseeing more green space, community facilities, footpaths, electric cars, smart, energy efficient, warm housing, zero waste and zero emissions. Many of these visions aim for transformed energy systems, for example exploiting local energy sources for both heat and electricity, with a local energy economy contributing to pro-active demand side services, energy storage and 'green' jobs and incomes: some scenarios even imagine cities in future becoming energy self-sufficient. These visions entail, often explicitly, significant overhaul of city infrastructures. But change also relates to repositioning existing city assets and artefacts as energy sources: these include surplus heat from industry, underground train systems, abandoned mine workings, sewers, rivers, subways and even data centres (Wald 2013). Technological innovation is opening up new possibilities to capture heat with improved heat pumps and fourth generation low temperature thermal grids (Lund *et al.* 2014).

On the one hand, the renewal of interest in urban-scale energy systems is surprising given recent European trends to increasing concentration of ownership by large scale corporations with generation facilities geographically remote from cities. On the other hand, however, local energy resources for cities seem to promise local governments a means to achieve numerous goals, from improved revenues to economic renewal and the welfare of communities to climate change mitigation. In the UK, as we discussed in Chapter 8, the local ambition to develop sustainable urban energy is well established and widely shared, but here as well as elsewhere in Europe it is proving more difficult to find secure and effective routes to translate ambitions into significant material change in cities.

In the preceding chapters, we have reviewed the social and political dynamics, and power relations, of energy policy processes and economic practices in relation to sustainable heat systems, and sought to identify where and why change and innovation are occurring, and where and why change is stalling. Here we discuss these issues of change and stasis, visions and obduracy, drawing a metaphor from the flow of energy through network infrastructures. The transfer of energy, a dynamic process, is enabled by the relative rigidity of the network whose configuration opens up some possibilities while closing others down. In various ways we argue that dynamic processes of change imply a degree of rigidity on which the dynamics depend. We use this abstract metaphor to highlight a coupling between how fixity and flow are *described and understood*, and not just by us but by the myriad civil servants, politicians, facilities managers, households, financiers, consultants, activists, etc., who form the cast of characters discussed in this book. What is regarded as fixed and what changeable conditions a range of decisions related to sustainable heating in cities, particularly where those decisions concern substantial long-term commitments and interdependencies, as is characteristic of city infrastructure. This is not to say that conceptions of what might change and what can be relied upon are themselves fixed or invariant across different people and organisations, or across different periods. Indeed, the socially negotiated character of what is considered changeable and what fixed is crucial to understanding socio-technical change in infrastructure.

The socio-technical and urban studies perspective applied to sustainable heat

The energy systems in European cities, whether the large networked systems of gas and electricity, or more locally customised CHP and heat networks, emerged out of the mutually constitutive and recursive interactions between technologies, energy resources and societies. Industrial urbanisation and the growth of fossil-energy use went hand-in-hand. The large networked systems of universal provision built in the twentieth century were woven into societies already reliant on significant flows of energy, and their construction transformed and deepened this reliance. But this dynamic of expanding energy systems in European societies was also embedded in a series of interlocking governance institutions, social interests and ideologies whose perceived stability enabled major commitments to infrastructural change to be made. Expanding systems of mass production and mass consumption provided reliable demand growth which utilities could be confident of accessing under various forms of public authority protection, not least local, regional or national monopolies. Financial solvency of these enterprises, often owned by local or national governments, was underwritten by states with justification relying on a more or less stable Keynesian understanding of the role of governments in sustaining economies (Coutard 2008; Graham and Marvin 2001). Furthermore, the determination of public authorities to plan and fix the contours along which energy networks would grow stemmed in part from dissatisfaction with the seemingly anarchic networks that had emerged when too many options had been held open, that is, when competition among systems rather than planning had guided development, with inefficiencies across London's early patchwork of electricity networks regarded a paradigm case of dysfunction (Hughes 1983).

Today's European cities thus inherit in the physical infrastructures of their energy networks the sedimented politics, and temporary resolution, of struggle between different interests, which directed resources along certain routes, while constraining or marginalising others. The conditions supporting these processes characterise a particular historical period and have since changed dramatically (see Chapter 2). For example, continued expansion in demand for electricity could not be relied on forever, and indeed in Britain its end came sooner than either the UK Government or its nationalised electricity industry anticipated, with the decline of British manufacturing (Helm 2004). From the end of the 1970s, state protection of energy system growth, previously regarded as ensuring the avoidance of economically irrational outcomes, itself became a problem: it was now regarded as the source of a new economic irrationality of excessive investment, which neo-liberal analyses positioned as distorting ideals of economic efficiency.

The material legacy of past political compromises and investments itself plays a role in changing conceptions of change and stability. The legacy creates interdependencies between human actors and artefacts, which confer specific capacities on energy users, shaping structural divisions and opportunities governing future innovation. For example, the inheritance of large networks with multiple energy inputs and large numbers of users was a relatively stable frame over which new dynamic forms could be laid. From this foundation, liberalised market structures could be enacted within which buyers and sellers are envisaged to interact (more) freely, with coordination mediated by price signals.

Thus during the twentieth century, overarching principles governing energy systems co-evolved with those systems and broader shifts in political economy. Western European state commitments to macro-economic management of demand in welfare capitalism gave way to commitments to the extension of markets as the means of decision making across society. It was argued that the allocation of resources across inherited energy systems would be more efficiently managed by markets. This has resulted in common European policies for the liberalisation of energy, structured around theoretical principles of competition, and increasing privatisation of assets previously under public ownership.

The adoption of climate change mitigation as a goal for energy systems across European countries, however, sits in tension with the freedom for energy suppliers to choose technologies and fuels, necessitating new state interventions to shepherd investment decisions. Furthermore, slow rates of reinvestment in liberalised energy systems have shifted from being regarded as an efficient outcome (as 'gold-plated' assets were being 'sweated') to being regarded as a threat to energy security by stretching capacity margins (Helm 2011). The political economy of state responses to the challenges of mobilising apparently reluctant investment into some technologies, but not others, continues to be governed according to a calculative economic logic centring on cost minimisation and profit maximisation in relation to measures of state and business competitiveness. The development of low carbon energy systems is thus located as a matter of market decisions, regulated by an evolving economic framework of price support mechanisms, long-term concession contracts between public and private sectors, and state financial guarantees. For electricity systems, where political and regulatory attention to reinvestment and decarbonisation is longer-standing, the absence of dependable market conditions across the lifetime of low carbon assets is increasingly regarded as problematic, and has drawn governments in to making new forms of commitment, such as the UK's long-term price guarantees underpinned by contract law, or new markets for reserve generating capacity, fixing conditions through which commercial investment is expected to flow (Department of Energy and Climate Change [DECC] 2011).

In comparison with electricity, sustainable heat has received less attention. Differences in inherited infrastructure contribute to structures of perceived opportunity and uncertainty in different cities. In cities with large district heating networks new low carbon forms of heat generation, such as solar thermal farms, can be experimented with as the network and its customers can be relied on to take the heat. Where gas networks predominate options to displace fossil fuels are more limited given doubts about the volumes of non-fossil forms of gas that can be relied upon (DECC 2013). In these cities a transition to sustainable heating disrupts reliance on existing network configurations, but there is a wide range of forms alternative infrastructures may take and corresponding difficulties judging between them.

Judging the relative value of future energy options

The different inherited configurations of energy technologies for heating and built infrastructure in different European states and cities mean that they have different capacities for innovation in relation to sustainable heat, and different conceptions of best practice. Judgements concerning the cost and carbon economics of a given heat supply technology, which are crucial to legitimating investment and state support, vary from place to place. Most obviously this is because they are conditioned by differences in built form, existing infrastructures, indigenous skills and supply chains and the availability of energy resources. But different ways of appraising a technology also reflect interpretive flexibility (Pinch and Bijker 1984) in what objectives the technology is understood to contribute to, which may be mobilised to serve different interests. Construing district heating as a means of ameliorating problems in balancing electricity systems[1] leads to considerably different appraisal than construing them only as large central heating systems, burning fuel in response to heat demand.

Judgements of viability for heat networks are often sensitive to a wide range of uncertain variables. To the extent that local decisions to develop district heating depend on constructing a business case on the basis of the long-term evolution of such variables, such as long-term interactions with other energy systems, the result is likely to be multiple competing interpretations. This compounds the difficulties of coordinating multiple actors who, in any case, see different virtues and drawbacks in any proposition (Chapter 7). These variables cannot all be regarded as following their own autonomous path, but may depend on other actors' strategic decisions made in response to a proposed system. Such responses are difficult to evidence as they are often based in complex and confidential business analyses, but their possibility leads to suspicion and distrust among interested parties. For example, one officer of a municipal ESCo in the South of England described to us how incumbent utilities would try to poach potential commercial heat customers by offering 'silly prices' for gas and electricity. In another example, an employee of a commercial heat network operator in the North of England described his company's strategy in relation to local authority pressure to extend the heat network to connect with a rival system. Neither company, he suggested, wanted to be seen to refuse the local authority's request, but both saw their position in future negotiations as shaped by how their respective businesses developed in the intervening period. Both companies would build their networks towards each other slowly, while trying to avoid being the 'distressed party' when they eventually met.[2] Thus while the local authority wanted to secure the efficiencies of an interconnected system, the companies were interested in establishing advantage over each other or even avoiding interconnection entirely.

The 'value' of district heating assets to their owners and other stakeholders are not, thus, determined solely by inherent properties of their material structure, but also by their relation to other actors' problems and objectives which may be perceived as more or less stable. Here interpretive flexibility significantly complicates multi-organisation interactions and analysis of business models. An incumbent utility might regard district heating as a threat to its sunk investment and either engage in passive blocking (Summerton 1992), shaping prices (Russell 1996) or even bidding to operate a proposed system to control its scope. A commercial district heating specialist by contrast might see a proposed scheme as an opportunity to lock in its presence in a city, perceiving future advantage in interaction with a city government committed to sustainable energy.

Sustainable heat policies – where is the problem of heating located?

Meanwhile, heat policies in Europe and the UK, rather than setting clear conditions for managing such conflicts of interest, continue to be marked by intersecting uncertainties associated with financial market collapse in 2007, ensuing economic recession and resulting constraints in public finances. Energy efficiency investment, despite its attributed cost and energy saving and social benefits, has continued to be incremental and slow. Climate leadership is a matter of continuing internal disunity and weakening of commitments to specific targets such as those for renewable energy and energy efficiency is evident (see Chapter 1).

In the UK, the 2008 climate legislation also prompted considerable expansion of policy activity on heat and its decarbonisation. Initial technocratic scenarios envisaging an all-electric energy future, combined with improved building efficiency and demand reduction, positioned heat supply as a residual issue, to be tackled once electricity had been decarbonised. Weakening faith in and commitments to the all-electric future have led to pragmatism over the search for affordable ways to meet carbon targets (see Chapter 4). The more pragmatic shape of current policy seeks to integrate appraisal of options for low carbon and low energy heat in a systemic analysis of energy, so that the potential for understanding the strategic interaction between low carbon electricity and heat is strengthened (DECC 2013). This more systemic analysis incorporated scenarios for diverse heat technologies for buildings, including electric, gas and hybrid heat pumps, and urban heat networks using a range of energy sources. There is increasing interest in the potential cost savings derived from synergies between the electricity network and decentralised heat networks with thermal storage; the latter is regarded as potentially reducing peak electricity demand and therefore reducing the costs of electricity grid reinforcement.

This pragmatic turn has not resulted in the articulation by UK central or devolved governments of a clear vision for the socio-technical configuration of future heating. The complexity of systemic interactions and interpretive flexibility of heat technologies is reflected in the wide variation in the outcomes of scenario modelling exercises, which in turn underpin prescriptions to keep a range of options open (Chapter 4). The UK Government thus explicitly states that it 'wants to make progress without prescribing the use of specific technologies' (DECC 2013: 79). Coupled with overarching uncertainties in energy policy commitments to decarbonisation and renewable energy, this means the political context within which other actors make decisions on sustainable heat is characterised by fluidity and uncertainty rather than fixity.

Neither is there as yet any obvious translation between high-level policy interest in exploring the potential systemic impacts of district heating and the means of implementation. Market allocation of resources for future urban heat technologies is kept perpetually in play, with the UK Government's *Carbon Plan* (2011: 6), for example, envisaging heat networks as competing with other low carbon heat technologies to minimise overall costs. But the commitment to retaining flexibility and responsiveness to changing conditions mean that there is no obvious market route to a competitive district heating system, given high initial capital costs and existence of an established gas grid serving urban buildings, with low taxes on domestic supply of gas. While UK climate change targets imply widespread transitions away from dependence on the gas grid for heating (DECC 2013), in our research we have not found any significant actor in the UK who regards large scale district heating as a solution to their own near-term problems. City authorities are identified as 'critical players' (DECC 2013: 50) in heat network development, but their expected role is ambiguous, varying between responsibilities to secure local heat network development, or to clear away market barriers (particularly knowledge failures) to enable other actors to choose whether to take on district heating. This contrasts with the European city-scale heat networks discussed in Chapter 3 where in various ways large scale district heating could clearly be identified as solving local challenges. In Denmark and Sweden the 1970s oil price rises stimulated local authority planning and development of district heating as protection for communities against price volatility, at the time regarded as a significant, near-term problem. In Norway heat networks were initially pursued by electricity engineers interested in alternative means of dealing with constraints on electricity distribution networks. The adoption of minimum energy efficiency standards for waste incineration, which effectively required the use of heat, created another constituency, waste management companies, for whom heat networks solved a problem. Similarly, in Rotterdam surplus heat was an environmental problem to which the harbour industries sought a large heat network solution.

In the UK large scale district heating is not clearly located as the solution to any particular actor's critical problems and the role of local authorities is ambiguous. Despite these challenges, the logic of local political experiences, translated into particular commitment and purpose, is evident in the innovative actions of some UK city governments who *have* managed to invest in retrofit of housing, public buildings, CHP and district heating. The system builders in these cases are an assemblage of willing politicians, public officials and small enterprises, improvising means to configure the necessary organisational capacity, expertise and resources (see chapters 7 and 8). The strategy has exploited the interpretive flexibility of district heating to serve different locally articulated goals, which range from economic renewal and branding to social welfare, carbon and energy saving and revenue creation. Initiatives have moved forward where there is potential for alliance building through exploitation of the interpretive flexibility of the technology to solve the different problems articulated by actors. The processes of translation between different interests, and enrolment of others into support, positions district heating as a solution to multiple problems and a means to pursue each party's interests. Local housing authorities or housing associations with older housing stock for example may need to meet increased housing standards; local welfare campaigners may push for an end to fuel poverty through affordable warmth; council finance teams may be searching for improved revenues from housing stock or reductions in council energy bills; local politicians may be seeking visibility as champions of local business or economic regeneration and 'green city' reputational capital; and those charged with advancing the city's sustainability strategy perhaps need to find a means to justify a proposed waste incineration facility. Large utilities in turn may need to meet supplier obligations to invest in energy efficiency for low income households. Each of these interests could be enrolled in development of district heating. Housing renovation teams in Aberdeen and Glasgow for example (chapters 7 and 9) used district heating as a means to reduce fuel poverty, and enhance social welfare, while improving housing revenues and sustainability credentials, and mobilised funding from utilities. In other contexts, such as the debate over zero carbon homes, advocates may translate district heating technology into a 'fix' for new build housing standards. However, each of these locally articulated objectives can be met with small, bounded networks. Processes of alliance building and translation are often structured by time-critical events, formed around time-limited grants or incentives as in the UK Community Energy Programme, meaning aggregation of different objectives into a shared goal to develop more comprehensive infrastructure is highly unlikely.

Development thus far remains only a small step towards sustainable heat in cities. In these circumstances, implementation has largely focused on small scale, stand-alone and opportunistic projects and incremental energy efficiency improvements, as discussed in Chapter 8. In a pattern pre-dating the climate legislation, intermittent and changing policy initiatives and incentives exacerbate these difficulties. Such small systems concentrate risk and cost across relatively small numbers of users, which tend to reinforce the evaluation of district heating as uneconomic. By contrast, risks associated with equivalent modification of incumbent infrastructure are effectively shared across millions of customers. Heat networks may remain small and fragmented, hence failing to secure the scale and scope efficiencies achieved by earlier European heat networks. The contrast between fragmented heat network development and more extensive systems is significant, with the latter demonstrating, both in practice and in theory, lower average costs and opening more options for interaction with broader energy systems (chapters 5 and 6). There are risks in the UK that a policy feedback loop may entrench these patterns, as happened with the Community Energy Programme in the early 2000s: while policy seeks to keep options open and learn about district heating development in a UK context, it unwittingly contributes to conditions under which the heat networks that do develop are regarded as disappointing, potentially further destabilising policy and investor interest in the technology.

Thus the 'pragmatic turn' in UK energy policy, in seeking to keep options for sustainable heat open, fails to change current conditions in which no actor regards large scale district heating as a solution to their own critical problems. Instead, locally bounded objectives drive activity in small systems. While efforts to develop district heating grow they are only weakly channelled, instead relying often on chance coincidence to create opportunities. There is therefore as yet no resolution in the UK to the ultimately political questions of who decides the future of heating, and the established gas network, how a workable consensus over the issues will be forged, and where the distribution of costs and benefits will lie.

Deployment of district heating in European countries with historically limited provision – how can systems be coordinated?

Historically, strong locally based actors, notably municipal authorities, and/or their arms-length enterprises, have played a critical role in the development of district heating. That is, district heating as an objective was coupled with capacities to plan and coordinate development, particularly to draw heat sources and heat users on to a network and keep them there. This was important to reduce risks that assets would be stranded and hence support decisions to commit investments to systems that would grow over time. The insertion of a heat network into a community depended on the power of system builders to shape the decisions affecting heat sources and users, again, returning to our metaphor, holding them more or less fixed as the channels through which network expansion would flow.

Prior to the liberalisation of energy, these capacities in relation to heat networks tended to be held by local authorities. In Denmark specific new powers and procedures of heat planning were institutionalised, while in Sweden development was embedded in traditions of strong autonomous municipal planning and coordination of infrastructure. Confidence in municipal capacities to achieve the coordinated changes necessary to bring planned systems into being, coupled with stable central government policies, regulation and taxation, meant system builders could access long-term investment finance at low rates of interest. Protection of network development thus contributed to keeping costs low and, along with regulatory protections against monopoly exploitation, supported the benefits users perceived. These were the foundations of perceived long-term security for mutually dependent users and suppliers. Summerton (1992) established the necessity for such coordination as fundamental to developing shared infrastructure for heat, and the resulting creation of long-term mutual interdependencies between system actors committed to making the operation successful: 'the physical grid is paralleled by an invisible grid that … is as strong as the physical one' (p. 258); as she comments, the hardware of the network seemed more malleable than organised interests. The physical grid acts as a political artefact; it confers control on its owners/operators in relation to supply of heating to an area and its costs, efficiencies and energy sources. The resulting actors in this system are not just the original developers, but also its users, suppliers, politicians and regulators whose specific roles and capacities are brought into being by it.

Our findings have extended Summerton's work in two particular dimensions. First we have shown that the differing forms of liberalisation introduced towards the end of the twentieth century have differentially affected the potential for coordinated action to develop shared infrastructures such as those for sustainable heat. Second we have shown that, while liberalisation has generally sought *not* to locate capacities for energy system development with public authorities, local governments nonetheless continue to play important coordinating and stabilising roles in the development of heat infrastructure. The capacities and capabilities of local government to play these roles varies in different European societies, in relation to the history of municipal authority over energy, and the relative powers of city politicians and officials over taxation, revenues and strategic direction.

In Norway, state licencing of district heating provides an institutional frame for construction of a local 'invisible grid' around heat network development where local actors consider the technology a solution to their own critical problems. A licence is only granted where credible commitment across a user base can be demonstrated, and the ability of an applicant to recruit those commitments is supported by conditions imposed by the licence (including a price cap, service standards and public authority rights to assume control of the network at licence expiry). Once granted a licence holder's network development plan is protected by the exclusion of other district heating systems from the licence area, and by local government planning rules requiring new developments to connect. In Bergen we found development of district heating initially proceeded with little interest from municipal government, but rising salience of climate change politics has led it to collaborate more closely with the district heating company, helping to identify and shape opportunities for further system development.

The Netherlands represents an intermediate case between the UK and Norway on a notional continuum of capacity for coordination in liberalised societies. The Netherlands' Government has given less central direction to heat networks, but has nevertheless regulated maximum user prices, and monitors the returns made by companies to ensure fair pricing. Strong city governments have however coordinated long-term cross-sector collaboration, used planning and rent control to draw in users, and, in Rotterdam, invested significantly in network infrastructure to prevent the project from stalling. While the Rotterdam initiative emerged from collaboration among the harbour industries, the voluntary and improvised character of this part of the invisible grid proved unstable, with the project eventually relying on the relatively fixed structure of the municipal waste contract. Collaboration between municipality and private sector business has however proved difficult in relation to heat infrastructure development in Amsterdam, where the city prioritises social objectives and the energy company prioritises profitability.

In the UK recent development of sustainable heat policies has not been accompanied by effective new mechanisms to coordinate a secure user-base for district heating. Planning guidance has sought to give authorities the option to require new development to use district heating, but in practice the policy has had limited effectiveness and proven to be unstable. Instead, existing capacity for construction of an 'invisible grid' is relied upon, resulting in systems connecting buildings in common ownership (such as university campuses or social housing estates) or commercial investment in schemes serving clusters of large, usually public sector buildings, with attendant risks of cherry-picking (see chapters 6 and 7). These circumstances reinforce the pattern of small scale heat network development. As the analysis of business models shows (Chapter 6), small heat networks may be envisaged as part of larger future systems, but the necessary 'future proofing' adds costs which are difficult for both public and private sector organisations to justify in the absence of effective mechanisms to secure a growing user base.

Comparison between these three European states shows that within the notionally common framework of liberalised energy markets, decisions to develop district heating are not based in universal or invariant techno-economic rules. Rather, they reflect variations both in the socio-material inheritances of cities, and in policies and regulations structuring near-term drivers to develop heat networks and the capacities actors hold to achieve coordination by shaping others' decisions. The balance between social, environmental and commercial objectives structured into assessment and regulatory frameworks is particularly consequential for such capacities. These decisions are made in the political sphere where techno-economic tools of calculation are vehicles for struggle over the relevant costs and benefits to be included in evaluation, and how these are shared. The resulting metrics frame the distributions of risk between stakeholders, limiting some possibilities and opening up others.

The likelihood of increasing deployment of district heating in European cities is thus variable across countries in relation to different enactments of liberalisation. Amid this variability, there is a common pattern of more extensive and complicated interactions between public authorities and commercial organisations in design, development and operation of district heating than was evident in the twentieth century municipal model. The consequences of this distributed activity across public and private sectors is considered in the next section in relation to the UK.

Public-private partnerships for sustainable heat infrastructure

The role of private sector interests in contemporary district heating development stems not just from the liberalisation and privatisation of energy systems. City governments have had to restructure to manage declining budgets and to prioritise a form of market governance of public services through use of commissioning and outsourcing, which has to be made to work in relation to continuing responsibilities for local welfare. In this resource-constrained context, an array of technical, legal and commercial skills and expertise which historically underpinned local authorities' ability to provide services directly, and which are important in developing district heating, are no longer necessarily held 'in-house'. Although many local authorities are developing energy and carbon management plans, capacity to pursue comprehensive redevelopment through urban retrofit and city heat networks is precarious. While sustainable energy is a statutorily *permitted* function of local government in the UK, it is not statutorily *required*. Local energy investments are hence always a likely casualty of budget constraints. Central government initiatives have in addition proved unpredictable and intermittent, further weakening local capacity to maintain a consistent strategy. Hence even where local authorities have positioned local energy as a priority, these pressures constrain the scope to invest in building in-house skills and expertise. The loss of skills along with direct service provision is acknowledged by municipal officers: '*We used to run energy networks in [West City], but that was the old corporation*' (West City Director of Sustainability).

Instead these skills are located mainly in private corporations and have to be 'bought in' by city authorities. The outsourcing of energy initiatives to third parties paradoxically contributes to limited local authority expertise, because it outsources opportunities to learn from experience. Instead, local authorities rely on a narrower, more generic set of skills centred around procurement of external support. In theory procurement processes establish a competition between bidders which should ensure public authorities can achieve 'best value'. In practice the limitations of local authority specialist knowledge can leave them vulnerable: one senior officer in a large consultancy described a common approach to bidding for contracts among companies in the UK as 'competing to confuse the customer'. The possibility that expertise bought in may not be all it appears is recognised by local authority officers:

> I'm very wary of these bankers who come to the table and say, 'Well as far as energy performance contractors go, we know this, we know that,' but realistically they don't know anything, they just want quick fixes to a problem, commercial fixes.
>
> *(West City Manager of Urban Design and Development Services)*

> I think we've fallen for the bullshit that comes from the private sector about 'we're the only people that can fix this problem' … so council needs to understand how to drive a harder bargain from them.
>
> *(West City Sustainable Future Programme Manager)*

In part these difficulties stem from the infrequency of interaction each local authority has with commercial specialists, restricting scope for local reputation building and monitoring. Current UK and Scottish Government programmes discussed in Chapter 5 aim to support local authorities procuring technical and business advice, and the increase in activity coupled with knowledge exchange forums such as the UK District Energy Vanguards network may contribute to ameliorating this issue.

Nonetheless, where municipal authorities seek to engage commercial companies in the actual construction and operation of heat networks, relationships seem to be marked by structural distrust. This reflects perceived differences in the objectives of the city authority and large scale private utilities, which lack any formal obligation to work with cities. In the West City case study, for example, the electricity distribution network operator believed utilities such as itself were regarded by city officials and politicians as 'commercial animals who are going to rip [them] off, charge [them] lots of money' (West City Distribution Network Operator Business Development Manager). City officials indeed distrusted the commercial operators:

> While [utility X or Y] may say they're doing it to benefit the city, structurally they work to the benefit of their shareholders.
>
> *(West City Sustainable Future Programme Manager)*

> You know, it's all about pounds and pence to them. And if they don't see a kind of a quick pay back for them, they're not so interested.
>
> *(West City Director of Sustainability)*

With limited budgets to invest in district heating and clear signals from central government that mobilisation of private finance is preferable to public funding, entrepreneurial local authorities seek to negotiate with commercial operators. As discussed in Chapter 5, an emerging UK municipal approach is to use the assets and resources held by the public sector to leverage commercial investment in pursuit of social and environmental goals. Officials sought to maximise the value of their strategic knowledge of future city development plans for the utilities:

> We hold a lot of data which is useful for these guys; we know where things are going to be built; we know where some of the difficulties are, and being able to bring that together at the city level is a pretty powerful tool to have.
>
> *(West City Sustainable Future Programme Manager)*

But the ability to play their hand successfully in this 'poker game' is conditioned by local authorities' relatively weak specialist technical and commercial expertise:

> Council at the moment doesn't have the skills and capacity to hold the private sector to account … Best option [for the council] would be to partner with a utility and take whatever margin it can.
>
> *(West City Sustainable Future Programme Manager)*

Concerns about public sector technical capacity are compounded by concerns that the poker game is likely to have more than one round given the incremental character of heat network development, particularly where capacity to coordinate a growing user base is weak. As local authority priorities evolve and unforeseen opportunities arise, a new negotiation between a local authority and its commercial partner may emerge:

> And [the commercial partner says], well we're not doing that, it doesn't meet our trigger rate of worthwhile investment. So then that's shoved back on the council to make more investment. And do they make that investment with another provider, or do they stay with their [commercial partner …] who increasingly would be hard-hearted in business terms?
>
> *(Municipal ESCo Officer)*

While the municipal development models of the twentieth century relied on multi-organisation structures (Summerton 1992), contemporary partnering with commercial interests around heat networks introduces more complex problems over control of the development. A local authority may use its assets to lever commercial investment in an initial system that goes beyond narrow commercial objectives, but in so doing the system created becomes an asset controlled by the commercial partner. In subsequent negotiation, the partner may be able to use this asset to lever more funding or other concessions from the local authority.

The issue here is the means to resolution of structural tensions between commercial and social/environmental issues. What we are describing is how local authority officers perceive these tensions, rather than how they have played out in specific cases. But these concerns are important to how decisions are made, with the suspicion that the fluidity of relations with commercial partners may undermine local aspirations. With limited options to invest public resources in heat networks and retain control, trajectories for city-scale heat networks developed in partnership with the private sector are thus difficult for local authorities to envisage. Their relationship with commercial partners, able to exert control over network development, is another fluid site of uncertainty with which to contend. Plans may be in recurrent cycles of development for a decade or more, while physical construction of the envisaged systems may take much less time. In this sense current institutional and organisational processes appear more recalcitrant than physical change in energy networks and heating systems (Summerton 1992).

Governance of urban change and innovation for sustainable heat

Economic crisis, associated with financial deregulation and the rescue of the banking system through major public borrowing, has not this time resulted in the rise of a new 'grand narrative' to displace that of neo-liberalism, in the way that the 1970s crises over inflation and mass production industries resulted in the ascendancy of neo-liberal theories (Crouch 2011). This means that the historically unique demands of transition to a sustainable energy system continue to be envisaged as resolvable through market instruments. There is nonetheless increasing criticism of the uneven and fragmented shifts to renewable and low carbon provision, and in particular the incremental changes in relation to energy efficiency and low energy, low carbon heat provision (see for example the UK Committee on Climate Change 2013). The question is whether societal arrangements with this mix of regulatory market mechanisms and commercial decision making geared to short-term returns on capital can encompass the concept of long-term social value of climate stability.

One area where change could be made in accordance with theories of market exchange is in taxation of fossil fuels. This is ultimately a political question about reshaping the economic calculus by pricing in the societal costs of fossil fuel exploitation and carbon emissions, which would increase incentives for low carbon developments and radical improvements in end use efficiencies. Subsidies and tax incentives for oil and gas industries at present far outstrip incentives for energy efficiency improvements in buildings. European member states could act to end fossil fuel subsidies and to restructure energy taxation around the full costs of greenhouse gas emissions. These changes are advocated by the International Monetary Fund as a result of its critical assessment of state subsidies, and of the resulting social and environmental damage (Coady *et al.* 2015).

However, our exploration of urban sustainable heat suggests internalisation of the costs of externalities is unlikely to be sufficient to effect a coordinated transformation of energy provision. Energy liberalisation, and dispersal of activities previously concentrated within local government, challenge capacities to coordinate development of city-scale infrastructure. Whereas twentieth century system builders relied on state-organised monopoly control to mitigate the risks that large sunk investment would be undercut by competitors, contemporary investment either has to manage these risks or, as is beginning to happen in electricity generation, turn to the state for underwriting. For heat networks, even if relative energy prices were significantly altered, decisions about whether to develop the basis of an extensive system would be conditioned by perceived risk that envisaged users might choose an alternative.

As we have shown, regulators are critical actors in system building in liberalised economies, framing the scope and potential for long-term strategic investment in coordinated systems development and innovation. At present, the UK market regulator Ofgem has only a secondary responsibility to consider sustainability, and will act only if any changes improve relatively short-term system economics. There are alternative models, such as the public system operator model similar to that in European societies structured around a more coordinated and joint problem solving approach to energy governance (see for example Lockwood 2014). Whatever the specific model adopted, energy regulation for urban heat networks in localities where heat density is highest needs to provide a stable and predictable regulatory frame as a means to building the initial user base and future security for extension of network infrastructure. As in other sectors, market development requires basic protection of sunk investment by infrastructure developers through some form of financial guarantees, matched by licensing of operators according to sustainability criteria, and protection of user interests in long-term affordability and reliability of heat from a monopoly supplier. Given that a monopoly supply situation is the norm in such infrastructure, then options for non-profit business models and mutual enterprises need to be represented in development plans.

Internalising cost externalities would create a shared problem of higher energy costs across society, and regulation would need to establish the mechanism by which a shared solution could be created. But development would in addition require an organisation to take responsibility for creating a new system, that is, to regard the development of city-scale heat systems as a critical objective. While they struggle to improvise solutions in current unfavourable conditions, city governments are an obvious candidate for such an actor. They are not only unique in their long-term local presence and accompanying powers, their duties in relation to climate change and their necessary commitments to place, but they are also major users of energy for heating buildings and water and are increasingly faced with managing on fewer resources while finding routes to locally viable sustainable economies. The combined scale of city authorities, universities, colleges and health services, as well as other public bodies, means that they control significant local heat loads, with potential to collaborate in anchoring heat network development. As we have argued, however, these organisations frequently lack institutional capacity and technical capability for direct engagement in energy systems, and struggle to assemble a legitimate space for systematic low carbon innovation (see Chapter 2).

In the UK the role of central governments in devolving power and institutionalising local authority energy activities is likely to be critical, given the current lack of local autonomy and discretion over budgets and services. Initial steps are being taken, with proposed devolution of some fiscal powers from the UK Government to English cities such as Manchester; this is not however directly concerned with climate change and carbon budgets, but with attracting private investment into northern English cities and regions. There is also a risk that devolution of penury (Le Galès 2002) will be the main outcome of proposed changes, without necessarily creating new powers to coordinate strategic local investment.

The necessary counterpart to such a strategy for remaking the infrastructure of heat provision is a comprehensive energy efficiency programme to retrofit all buildings to a high standard of energy performance. Funding released from fossil fuel subsidies could be used for such national projects, with accompanying education campaigns to explain the value of the programme for public health, sustainable futures, local economies and jobs (Washan *et al.* 2014). Our research with households on the Wyndford estate in Glasgow shows that building retrofit and district heating technologies do not in themselves guarantee social benefits. Household responses to the renovation programme were diverse, and new systems of heat metering, billing and payment caused problems for some people who continued to accrue debts. To make sustainable, affordable heating the norm requires careful development work with households, and continuing interaction to ensure that people have a sense of control over their heating and electricity, and the resulting bills. These are not short-term initiatives, but a matter of working with localities in developing the strategy for effective retrofit of housing and heating.

Low energy, low carbon heating systems for effectively insulated buildings would be a significant step towards a zero carbon, affordable energy system, and offer a means of improved resilience of cities and local economic regeneration through sustainable local business and social cohesion. But the development of efficient city-scale new heating infrastructure poses a series of coordination challenges. To return to our metaphor, internalising the externalities of fossil fuels is akin to increasing the pressure of water fed into a pipe. But if the pipe is made of flexible material, or if its connection with other pipes is unknown, the water is liable to leak in all sorts of directions rather than move to any desirable target. Without closing down some of the complex uncertainties across energy systems, which likely means deciding to foreclose some options, such messy outcomes for heat in the UK are likely. A possible outcome of sustainable heat policy in the UK is an uncoordinated and inefficient patchwork of small district heating networks in cities (cf. Coutard and Rutherford 2011; Graham and Marvin 2001), echoing the UK's pattern of development of gas and electricity networks in the early twentieth century that came to be regarded as dysfunctional. Avoiding this outcome is eminently possible, but requires more directive intervention from government than reliance on incentives and competition. Many of the people we have met in our research, across governments and their agencies, local authorities, consultancies, commercial developers, universities and housing associations share deep personal commitments to sustainability and have worked with persistence and dedication in pursuit of low carbon, affordable heating. The achievements of these actors working in uncertain and shifting conditions is impressive, and there is considerable potential for their efforts to amount to significant and extensive change if they can be channelled more effectively.

Notes

1 For example, heat networks with electric boilers or heat pumps could absorb electricity at times of surplus and accommodate efficient CHP to supply electricity at times of scarcity.

2 Being the 'distressed party' meant different things for the two companies. One had a large heat source and few customers, so its advantage would depend on securing as much heat load as possible, thus avoiding the need to access the other company's heat demand. The other company had a more established network and was reaching the limit of its own heat production. For it a disadvantaged position in the negotiation would arise if additional load connected to the network in the intervening period, increasing its need for the other company's heat.

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INDEX

References to tables are in *italics* and diagrams in **bold**