Governing low carbon socio-technical transitions – a case study of district heating in Great Britain

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The candidate confirms that the work submitted is his/her own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

The work in Chapter 5 of the thesis has appeared in the following journal article:

Ruth E Bush, Catherine S E Bale, Peter G Taylor (in review), *Realising local government visions for developing district heating: experiences from a learning country*, Energy Policy 98 (2016): 84-96

Details of the distribution of work contained within the publications

- Data collection and initial analysis was conducted jointly by the candidate and Catherine S. E. Bale (both researchers were present at all interviews).
- The theoretical framing and further iterations of data analysis were conducted by the candidate alone.
- Writing of the paper was initiated by the candidate, with input on framing and conclusions in later versions of the paper by Catherine S. E. Bale and Peter G. Taylor.

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- Alongside contributing data for this paper and thesis chapter, the workshop outputs were used by other members of the research team to inform creation of an agent-based model of the DH development process (this work does not form part of the thesis).
- The candidate carried out all transcription and analysis of the data from the workshop.
- Writing of the paper was done primarily by the candidate, with input and advice to later versions by the co-authors.

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Abstract

District heating (DH) has the potential to play an important role in enabling a transition to a low carbon, affordable and secure energy system, because of its ability to utilise renewable and waste heat sources as well as to provide a means for energy storage and flexibility. Countries new to DH, such as Great Britain, are looking to establish innovations in governance structures, business models, and policy approaches to overcome the numerous and complex barriers that exist for increasing deployment of DH.

This thesis uses socio-technical transitions literatures to explore a case study of DH development in Great Britain, an example of a liberalised energy market and centralised energy system. 'Niches' are highlighted in the literature as playing an important role in enabling transitions. The processes that take place within niches enable the creation of a protected space where an innovation can be demonstrated and developed. Niche processes also act as a catalyst for driving change in the wider 'regime' of established norms and practices that have formed around the incumbent technology configuration. However, debate continues within the socio-technical transitions literature about how actors can develop the agency to govern for more radical change.

Using analysis of case study data, this work considers the potential of actors from across the sectors to utilise different governing measures to support niche processes and drive a transition to DH. The work shows that effective governing measures develop the capacities of niche actors to exploit tensions in the incumbent regime and enable strategic development of DH at the local level. This requires support from actors across geographical scales and sectors. However, actors' agency to govern a transition is strongly influenced by dynamics in the incumbent regime. Support for niche processes needs to be complemented with activities to bring about destabilisation of the incumbent regime.

Table of contents

List of figures

List of tables

Abbreviations

DECC – Department for Energy and Climate Change

DH – District heating

ECO – Energy Company Obligation

EU – European Union

GLA – Greater London Authority

HNDU – Heat Network Delivery Unit

IEA – International Energy Agency

LA – Local authority

LEP – Local Enterprise Partnership

NA – National Authority

NUTS – Nomenclature of Units for Territorial Statistics

RA – Regional authority

RHI – Renewable Heat Incentive

RIA – Regulatory Impact Assessment

UK – United Kingdom

1. Introduction

1.1. The challenge of mitigating climate change

Mitigating the most dangerous effects of climate change requires significant reductions in greenhouse gas emissions across the world within the coming decades (IPCC, 2014b). In a review of climate mitigation scenarios, the International Panel on Climate Change found that scenarios where warming was likely to remain within 2^{o}C were characterized by atmospheric concentrations of about 450 ppm CO_2 equivalent in 2100, requiring substantial reductions in greenhouse gas emissions by the middle of the century (p.10, IPCC, 2014c). Even by limiting warming to 2^{o}C, there are likely to be significant and life-changing impacts on millions of people and species (IPCC, 2014a). It is therefore widely argued that it is crucial to introduce measures to reduce greenhouse gas emissions at sufficient speed to ensure effective mitigation.

Finding a way to drive decarbonisation within the necessary timescales to mitigate the most dangerous effects of climate change is critical. Greenhouse gas emissions are produced through activities across the economic sectors (see Figure 1). The largest proportion of emissions is produced from electricity and heat production, which account for a quarter of all greenhouse gas emissions. It is this sector that forms the primary focus of this thesis.

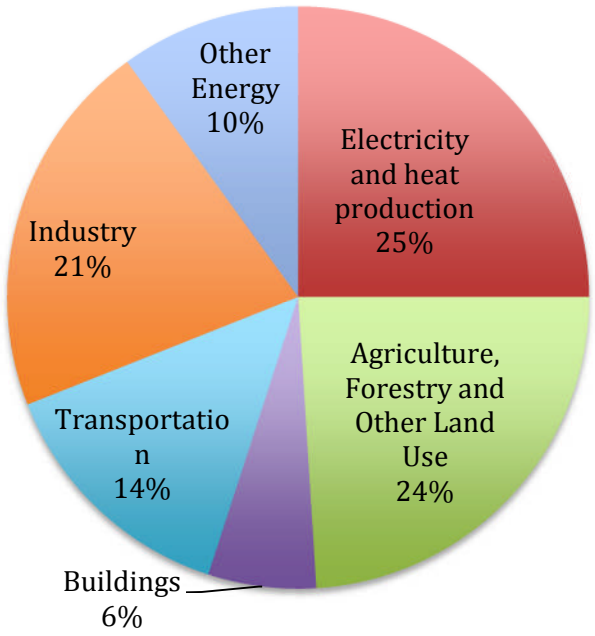

Figure 1: Global direct greenhouse gas emissions by economic sector in 2010 (p.9, IPCC, 2014c)

Numerous visions and scenarios suggesting technological and behavioural innovations to achieve decarbonisation of heat and electricity have been developed over recent years (Connolly et al., 2014; IEA, 2013; Delta Energy & Environment, 2012). Arguably, the challenge is no longer about finding plausible scenarios for how a decarbonised energy system could be achieved, but instead setting in motion the processes for delivering decarbonisation in a timely manner, whilst also ensuring secure and affordable delivery of energy services across the world. This thesis works on the basis that achieving energy decarbonisation in the timeframes required to mitigate the most dangerous effects of climate change requires active governing of the energy system. It draws on theories of technological change to draw lessons on how the complex systems of technologies, infrastructures, and their surrounding institutions, economies and cultures can be governed to enable a transition towards a decarbonised world.

There are a range of technological innovations that have the potential to contribute to energy system decarbonisation, each with distinct characteristics and challenges. This thesis considers the challenges of governing a transition to low carbon heating, focusing on the role of district heating (DH) in particular.

1.2. The role of district heating for decarbonising heat

The International Energy Agency described heat as the "sleeping giant of low carbon energy potential" (IEA, 2007). Heat demand accounts for more than half of the world's final energy consumption and is highly dependent on fossil fuels (Eisentraut and Brown, 2014). As nations begin to take on the challenge of decarbonising heat there has been a growing recognition of the potential of DH technology to play a role in achieving a low carbon energy system (Connolly et al., 2014). This decentralised infrastructure of highly insulated pipes can transport heat over several kilometres, taking heat in the form of hot water or steam from a heat source to where there is demand. Use of DH can enable utilisation of heat sources that would otherwise be wasted, such as intermittent waste heat from industrial processes, large-scale water source or ground source heat pumps, or geothermal heat. It can offer benefits of affordability with increased efficiency and use of waste heat sources. It can also offer flexibility to the wider energy system, with options of seasonal storage (for example, to enable use of solar thermal heat sources during winter), as well as storage of excess electricity generation from intermittent renewable generation such as wind turbines. This has been demonstrated in countries such as Denmark, Sweden and Finland, where the oil crises of the 1970s catalysed a transition to the use of DH, initially with gas-fired combined heat and power plants. The percentage of citizens served by DH in these countries now reaches 61%, 48% and 50% respectively (Euroheat & Power, 2013). As these countries begin to decarbonise their heat supply, they are able to make use of a wider range of low carbon heat sources than would have been possible without DH.

DH can operate at a range of scales, from networks that connect just two buildings, to networks that connect up entire cities. The most appropriate scale and location for a network are defined by the physical, cultural and institutional context of an area. However, schemes of sufficient scale to interconnect multiple and potentially intermittent heat sources (e.g. making use of waste heat from industrial processes alongside heat from CHP plants or thermal power generation plants), have been shown to offer greater environmental and economic benefits (IEA, 2005).

Therefore, this thesis is primarily concerned with the integration of large DH networks which offer these greater benefits for energy system decarbonisation.

1.3. Case study: Introducing district heating into Great Britain

In order to draw lessons for governing a transition to DH, this thesis uses a case study of the experiences of actors seeking to introduce DH into the energy system in Great Britain. DH delivery in the context of Great Britain is particularly challenging due to factors such as a highly centralised energy system, liberalised energy market, and extensive natural gas networks with building-level boilers providing a relatively cheap and familiar means of heat supply to consumers. Individual natural gas boilers used at the household-level currently dominate heating provision (DECC, 2012a). Accessing suitable financial investment options and securing customer contracts in the UK's liberalised energy market can also prove particularly challenging for proposed projects (Hawkey et al., 2013). At the last estimation, DH supplied only 2% of UK heat demand (Poyry and Faber Maunsell, 2009).

The UK and Scottish Governments have both recognised the potential of DH for playing an important role in a future low carbon energy system (DECC, 2012a; Scottish Government, 2015). Local authorities are seen as key actors for enabling suitable local conditions for development of DH schemes and ensuring strategic coordination. Many are seeking to take on the role of facilitating and supporting development and sometimes owning and operating schemes. This new role for local authorities in energy system development can often prove challenging due to lack of resources and limited experience of DH amongst local authority officers (BRE et al., 2013). DH policy approaches to date have largely focused on increasing the capacity of local authorities to better support DH development at the local level. In particular, resources have been prioritised towards developing heat maps to inform identification of potential projects and planning, as well as supporting local authorities through sharing best practice and enabling access to consultancy expertise. These activities are considered as transition governing measures within the thesis analysis and are explored in more detail within chapters 6 and 7.

Development is also supported by wider low carbon energy policies, some of which offer a potential source of financial support for projects.

Despite the attempts of policy makers to stimulate the development of new DH schemes, to date, successful projects have mainly been small-scale, stand-alone schemes that have relied on the endeavours of key local actors to create a supportive local context that enables delivery (Hawkey et al., 2013). To realise the full potential benefits of DH for energy decarbonisation, these developments need to move beyond one-off successes, to strategically located networks operating at a scale that enables use of multiple and intermittent heat sources and storage, integrated with the wider operation of the UK energy system.

1.4. Governing socio-technical transitions

The thesis draws on the socio-technical transitions literature to structure analysis of the case study for drawing lessons on governing a transition to DH. Within this developing body of literature, the complex interrelations between the social and technical dimensions of the world are considered as an interrelated 'socio-technical' system (Geels, 2004; Bergek et al., 2008; Foxon, 2011). Processes of social and technical change within a system are understood to be shaped by existing practices and norms that have built up around an existing technological configuration (called the socio-technical 'regime' (Geels, 2004). This socio-technical regime can act as a barrier to new innovations diffusing, and the regime – which evolved to support the previous technology - must undergo a phase of transition to a new, supportive regime in order to enable the innovation to diffuse and embed (Geels, 2004). In recent years, the study of transitions has increasingly turned its attention to governing and managing low carbon and sustainable transitions in response to the challenges of sustainability and climate change (Markard et al., 2012).

In particular, the thesis focuses on the role and governance of niche spaces for catalysing and shaping transition processes. Niches are concept in the literature which refer to a form of protected space where actors can experiment with and develop innovations to the point where they can induce changes in the incumbent

regime (Kemp et al., 1998). The concepts of niche 'shielding', 'nurturing' and 'empowering' processes have been introduced to differentiate between different types of governing activities that support the creation of a niche environment and build capacities to enable niche actors to influence wider regime change (Smith and Raven, 2012).

Niche shielding processes are on-going activities or policies that act to shield the niche from the barriers imposed by the incumbent regime. These can take the form of taxes, subsidies or grants that support creation of a niche space for the innovation to develop. Niche nurturing processes are activities that enable actors to develop and strengthen capacities to apply an innovation. Strategic niche management (Kemp et al., 1998) is seen as one approach which supports niche nurturing processes. This approach recommends that niches are strengthened by giving support to niche actors to learn and develop skills relevant to an innovation, create actor networks that enable the innovation to be applied effectively, and demonstrate the innovation's value to encourage future applications (Schot and Geels, 2008). A key aspect of strategic niche management explored in this thesis is the role of intermediaries, who are actors that facilitate learning and sharing of knowledge between niche actors (see chapter 7). Finally, niche empowering processes support the diffusion of an innovation beyond the protected niche space. Empowering processes may work to reconfigure the incumbent regime to enable the innovation to diffuse (to 'stretch and transform' the incumbent regime) or, to adapt the innovation sufficiently to enable it to diffuse without significant regime change (to 'fit and conform' with the incumbent regime) (Smith and Raven, 2012). This body of literature and its associated concepts are introduced in detail within the discussion of the theoretical approach used within the thesis, presented in Chapter 3.

Existing research in this area has largely focused on how various actors can manage the creation and development of niche spaces through shielding and nurturing processes. However, research is is still underdeveloped on how niche actors can develop the capacities and agency to shape these processes to influence the direction of wider regime change, and more empirical studies are needed (Smith and Raven, 2012). Indeed, a key question in the literature is whether it is

possible for niche actors to shape a transition at all (Hodson and Marvin, 2010). Despite protection provided by the niche, actors must still interact beyond the niche to access resources, skills and influence wider changes. Existing configurations of actors, institutions and resources can prevent actors achieving these objectives, particularly when they hold more radical visions for change that threaten existing practices in the regime. These key issues of actor agency, particularly for shaping niche empowering processes are discussed to various extents throughout chapters 6, 7 and 8. Chapters 6 and 7 focus on specific governing measures that actors use in the case study to support DH development. Chapter 8 shifts the analytical focus to consider the influence of regime resistance over actors' approaches to governing a transition to DH.

1.5. Thesis structure

The overarching research question of this thesis asks:

> What lessons can be drawn from a case study of DH development in Great Britain for actors seeking to govern a transition to DH as part of a low carbon energy system?

In considering 'governing' of a transition, this question seeks to explore the activities that various actors can undertake to drive regime change to better support DH. The work considers the potential roles and capacities of actors across the public and private sectors to influence regime change through taking specific actions. Therefore, the lessons drawn in the thesis are not aimed solely at government policy actors but at actors across the sectors.

Analysis to address the research question is focused at the level of local DH project development. Drawing on the socio-technical transitions literature outlined above, the actors involved in delivery of these local projects in the case study are conceptualised as niche actors who are seeking to create and develop socio-technical niches. Analysis is structured around the existing literature in this area on the role of niche shielding, nurturing and empowering processes in governing a transition to DH (Smith and Raven, 2012). The work primarily seeks to make an applied contribution relevant to actors in countries seeking to stimulate greater

utilisation and integration of DH as part of a low carbon energy system. However, the work also provides empirical evidence to support and contribute to these areas of the socio-technical transitions literature, in particular to the under-developed areas of niche empowering processes and actor agency.

1.5.1. Focus of the empirical chapters

There are four empirical chapters presented within the thesis. Chapter 5 presents a pilot study which is used to explore the case study in more depth as well as to identify promising areas for further and more focused investigation for addressing the research questions. Given the fast moving context of the case study and the relatively few existing studies focusing on DH in Great Britain, this pilot study was important for ensuring that the later empirical chapters were focused on pertinent areas. This pilot study focuses primarily on the visions of local authority actors in the case study, who are highlighted by the UK Government and Scottish Government as crucial actors for enabling strategic development of large-scale networks (Scottish Government, 2015; DECC, 2013c). The analysis explores local authority actors' visions for DH and comparing these to the development approaches used by local actors to deliver new DH networks. Taking on a role in DH development means taking on a new role in the energy system for these local authorities. Exploring their drivers and approaches therefore provides a useful first focus for empirical analysis. The chapter focuses on the following research questions:

1) What are local authority actors' visions for a DH transition?
2) What decision criteria and approaches are used to develop DH?
3) Do these approaches support realisation of local authority visions for DH?
4) What role do non-local authority actors play in supporting DH development?

Chapters 6 and 7 then go on to explore the potential of specific governing measures identified within the pilot study for supporting DH niche processes - heat mapping decision support tools in chapter 6 and intermediary actors in chapter 7. The early stage of DH development in the case study makes the socio-technical literature on the role of niches in transitions particularly relevant. The process of

DH development in the case study is therefore conceptualised as a form of niche creation and niche development to support longer-term regime change to DH. Since niche actors have limited control over shielding measures within the case study, analysis focuses on niche nurturing and empowering processes. For each governing measure, the chapters ask:

5) How does the governing measure support nurturing and empowering processes within the case study?
6) What lessons can be drawn from this aspect of the case study for governing a transition to DH?

The final empirical chapter, Chapter 8, then broadens the focus of the analysis beyond the niche, to consider the impact of regime resistance on actors' agency to deliver governing measures and support niche processes. The chapter considers the political narratives of actors working on DH development in the case study and uses them as an indicator of the type of transition approaches that actors are advocating more generally. Are they seeking to 'stretch and transform' the incumbent regime to enable alternative approaches to energy technology development and operation that suit DH? Or are they seeking to 'fit and conform' their approach to DH development within the existing norms and practices of the incumbent regime? The chapter asks the following three research questions:

7) What types of transition approaches ('stretch and transform' or 'fit and conform') are indicated by actors' translation narratives used to support DH niche empowering processes?
8) How does resistance from the incumbent regime appear to shape actors' translation narratives?
9) What lessons can be drawn from this analysis for governing a transition to DH?

1.5.2. Summary of research questions

A summary of the research questions and structure of the thesis are included below (Box 1). Figure 2 also shows a diagrammatic representation of the thesis structure and indicates where each of the research questions of stages 1 - 3 is addressed.

Box 1: Summary of the three stages of research questions

Overarching research question:

What lessons can be drawn from a case study of DH development in Great Britain for governing a transition to DH?

Local authority visions and development approaches for district heating in Great Britain (Chapter 5)

1) What are local authority actors' visions for a DH transition?
2) What decision criteria and approaches are used to develop DH?
3) Do these approaches support realisation of local authority visions for DH?
4) What role do non-local authority actors play in supporting DH development?

Exploring measures for governing niche processes within the case study (Chapters 6, 7)

Chapters 6 and 7 focus on specific governing measures to explore their potential for delivering niche processes (heat mapping decision support tools in chapter 6, and intermediary actors in chapter 7). For each governing measure, the chapters ask:

5) How does the governing measure support nurturing and empowering processes within the case study?
6) What lessons can be drawn from this aspect of the case study for governing a transition to DH?

Understanding niche actor agency in governing transitions (Chapter 8)

Following on from these analyses, chapter 8 broadens the focus of the work to consider the influence of regime resistance over actors' approaches to governing niche empowering processes. It asks the following research questions:

7) What types of transition approaches ('stretch and transform' or 'fit and conform') are indicated by actors' translation narratives used to support DH niche empowering processes?
8) How does resistance from the incumbent regime appear to shape actors' translation narratives?
9) What lessons can be drawn from this analysis for governing a transition to DH?

Now that the thesis research questions have been introduced, the following chapters of the thesis set out more details of the case study, theoretical approach and methodology used to inform the empirical chapters. Chapter 2 details the background and context of the chosen case study, giving an overview of the characteristics of DH as a technology, as well as the policy and historical context of the UK energy system. Chapter 3 reviews the socio-technical transitions literature and justifies the choice of theoretical approach in the context of alternative approaches. It also highlights in more detail relevant criticisms and gaps in the socio-technical literature and key aspects where this work seeks to make a contribution. Then chapter 4 outlines and discusses the methodology used to explore the case study and address key research questions.

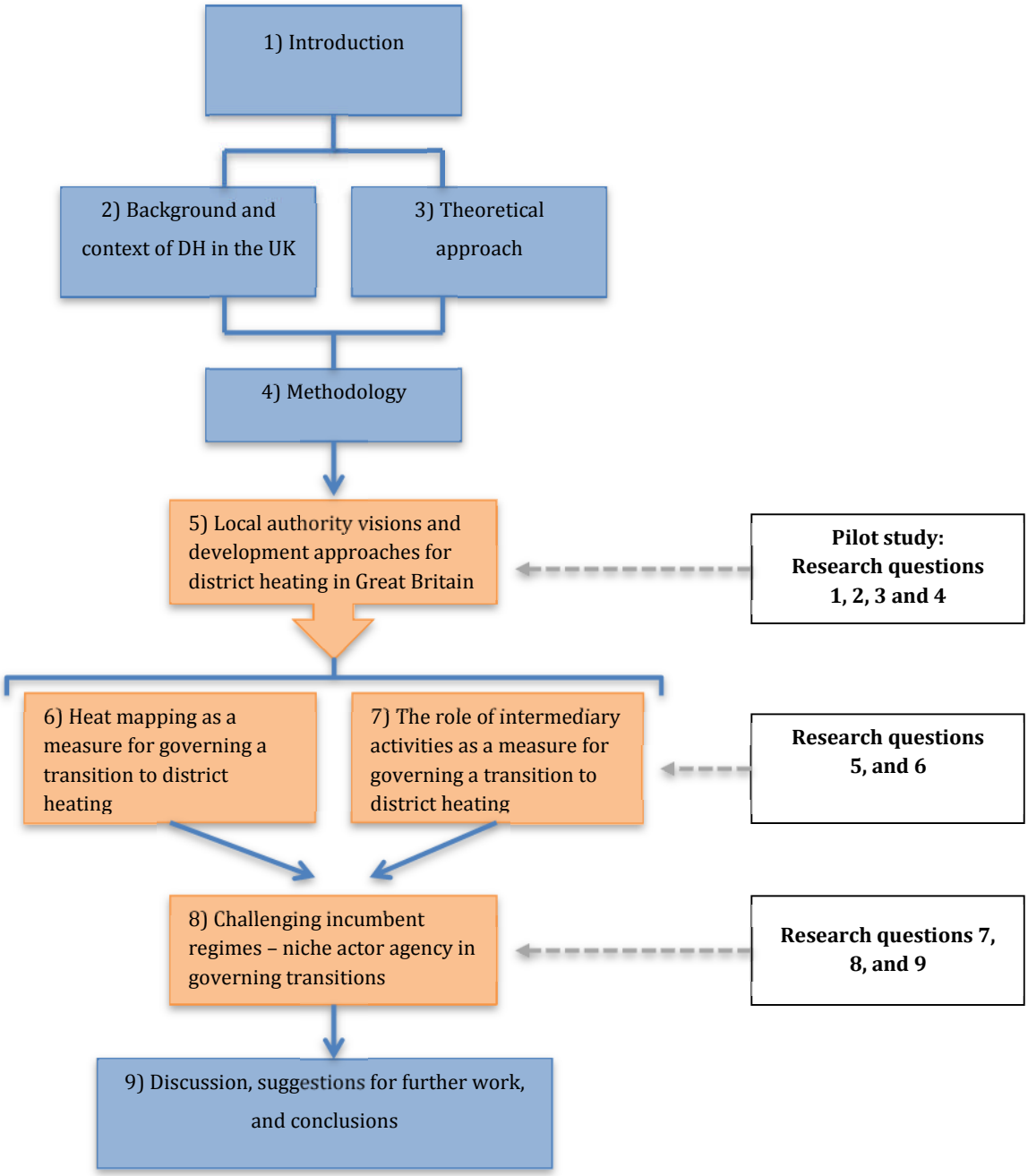

Figure 2: Overview of the thesis structure by chapter, indicating where each the research questions are addressed

2. A case study of district heating in Great Britain: context and background

As was introduced in chapter 1, the thesis uses a case study method to draw lessons on how to govern a transition to district heating. The choice of research approach is discussed and justified in detail in chapter 4. This chapter outlines key aspects of the case study's context and background and justifies the choice of case study for addressing the research questions set out in chapter 1.

District heating (DH) - which can sometimes be referred to as a heat network - is a decentralised infrastructure of insulated pipes that distributes heat to multiple buildings in the form of hot water or steam for space heating and hot water provision[1]. DH networks can transport heat over many kilometres, drawing heat from multiple sources and sometimes incorporating provision of short-term or long-term thermal storage. In some cases, DH networks supply heat to whole cities and their surrounding areas.

Through a similar means, district cooling can also be used to supply the cooling needs of multiple buildings. District cooling distributes chilled water through insulated pipes. Cooling energy is supplied from sources such as cold water from the sea, lakes or rivers. Alternatively, absorption cooling and heat pumps can also be used to chill the district cooling water to the required temperature of between 6^{o}C and 12^{o}C. Although many of the challenges of introducing district cooling are very similar to those for district heating, it is out of scope of the thesis since there was very little evidence of planning or delivery activities around district cooling at the local level within the case study.

[1] District heating is distinct from communal heating, which refers to distribution of heat from a central source throughout one building where there are multiple customers (Heat Network (Metering and Billing) Regulations, 2014).

Integrating and embedding DH into an energy system offers opportunities to provide low carbon heat supply, energy efficiency improvements across the energy system, flexibility for electricity network balancing, and security of supply through the diverse range of heat sources that can be incorporated into a network. Schemes can offer these benefits at a range of scales, depending on the context of the scheme, but a study of existing schemes by the International Energy Agency found that the greater environmental and economic benefits were achieved for the larger city-scale and district-scale schemes (IEA, 2005). These large-scale schemes are able to integrate multiple (and intermittent) heat sources and connect to a diverse set of heat customers for a stable heat demand profile and more efficient and low carbon operation. The focus of the thesis on a transition to DH specifically refers to integration of large-scale, interconnected networks that offer multiple benefits for the energy system in terms of decarbonisation and resilience.

In the rest of this chapter, section 2.1 details the key characteristics and considerations for developing district heating (DH). Section 2.2 gives an overview of the UK heat policy context, and details about existing DH projects. Section 2.3 discusses why this choice of case study was used to address the thesis research questions. Finally, section 2.4 reviews the relevant applied literature, covering research on both techno-economic and socio-political dimensions of DH and highlights key gaps in the literature. It also sets out the applied contribution of the thesis relevant to actors within the case study. In this way, the thesis seeks to make both a theoretical and applied contribution.

2.1. Introducing the key technological aspects of district heating

There are three components to consider within DH functionality: heat supply, distribution and demand. Integrating DH infrastructure into an energy system requires consideration of all three of these dimensions. Throughout the thesis, a reference to DH development refers to the necessary connection of all of these dimensions to enable a fully operational DH network.

Figure 3 illustrates how a low carbon energy system with integrated DH system might function, utilising multiple renewable heating sources, integrating thermal storage to manage peaks in heat demand, and reducing pressure on electricity demand for heating. In the figure, there are a range of options for heat supply, including solar thermal, geothermal and use of high-temperature waste heat from sources such as industrial processes or thermal power stations. In addition, electricity can be used with electric boilers for DH heat supply. Heat is transported from the various heat sources to areas of heat demand. In the scenario illustrated here, less dense heat demand areas such as in the suburban areas continue to use the gas network infrastructure, fed by biogas as a low carbon fuel. The next sections describe the characteristics and considerations for each of the dimensions of DH in turn: heat supply (section 2.1.1), heat distribution (section 2.1.2) and heat demand (section 2.1.3).

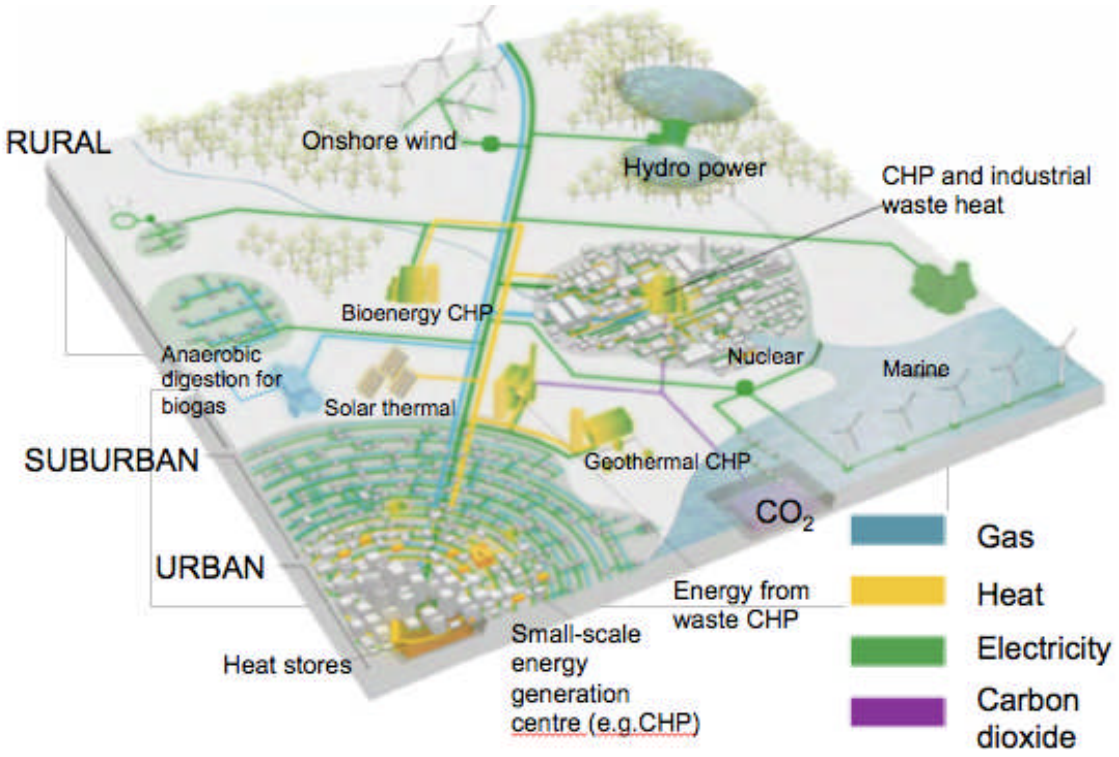

Figure 3: Illustration of how a low carbon energy system with integrated DH might function. (Diagram adapted from DECC (2015), p.9)

2.1.1. Heat supply

The need to supply low carbon heat has brought an increased interest in DH because of the flexibility of heat supply options that can be integrated into use with the technology. In the past, the driver for use of DH networks in countries with

large heating demands was for energy efficiency gains that could be achieved using them with coal or gas-fired combined heat and power (CHP) plants, feeding the generated electricity in an electricity grid and using the heat to supply a DH scheme. Use of CHP plants can enable increased efficiency of the energy system as a whole, since the heat generated during the process of electricity production at combustion power plants is captured and used, instead of treated as a waste energy. Although CHP plants continue to form an important heat source to DH networks, alternative low carbon heat sources are increasingly being incorporated into networks. Combustion of non-recyclable waste (mainly composed of biomass-based waste) in an energy-from-waste plant is one potential low carbon source, again offering the potential to generate both electricity and heat. Renewable sources of heat include geothermal heat, solar thermal, along with biomass and biogas used within boilers or CHP plants. Recovery of waste heat from sources such as industrial processes, or thermal power generation is another important potential heat source. Low-grade waste or secondary heat sources can also be used as a heat source, combined with large-scale electric heat pumps to increase the temperature to the required level for the DH network. For example, in Helsinki, Finland, an 82MW heat pump is used to increase the temperature of purified sewage water from 50^{o}C to 62^{o}C. During the winter, this is used to pre-heat the DH water before finally using boilers to increase the water temperature to the network operating temperature of 80^{o}C (Element Energy and Carbon Alternatives, 2016). Electric heat generation more broadly can also be used to generate heat, offering an option to utilise electricity when the price of electricity is low, or for electricity grid balancing purposes to manage intermittent renewable electricity sources. Use of electric heating sources in conjunction with appropriately located district heating can also offer efficiency gains over individual building electric heating systems by reducing the overall installed capacity required to meet peaks in heat demand.

DH also offers the opportunity to make use of thermal storage over the short-term (hours / days) or long-term (across seasons). Thermal storage is technically simple, typically storing the heat in a large body of water in an insulated water tower or underground pit. Its use can also reduce the need for installed heat

generation capacity to meet peak heat demand points, and instead enables a more stable heat generation profile where the system draws on the stored heat to meet peak demand. Seasonal storage is particularly useful for making use of solar thermal hot water generation during the summer months, and storing it for space and water heating until it is needed during the winter. The diversity and number of heat sources that can be integrated into DH systems offers flexibility and security of supply that would not be possible without the presence of DH infrastructure.

2.1.2. Heat distribution

Heat is distributed from its source via a network of insulated pipes, usually using hot water of between 60°C – 90°C, although steam can also be used where the heat source is at a high temperature. DH infrastructure has a lifetime of between 40 – 70 years (Frederiksen and Werner, 2013). For large-scale networks, transmission pipes are used to transport the heat at high pressure and speed over longer distances, and then distribution pipes are used to deliver the heat locally to points of demand. Depending on the heat demand required, transmission pipes have a diameter of up to 1.2m and are usually made out of steel. Heat loss is minimal in larger pipes due to the lower surface area of exterior pipe per cubic meter of hot water being transported. The longest transmission pipeline in Europe covers a direct distance of over 30km (Andrews et al., 2012). Heat exchange units are used to transfer heat from the transmission pipelines into local distribution networks, where smaller and lower cost pipes (which can be made out of plastic for system temperatures that normally stay below 80°C) are used to supply to each point of demand, via another heat exchanger into a building's central heating and hot water system (Wiltshire et al., 2014). Heat losses of systems are typically around 10 – 20%, but these can be much lower when a system's transportation distance is low, e.g. the system is supplying to an area with a dense heat demand and the heat source is close to the place of demand.

2.1.3. Heat demand

The heat demand profile of a DH scheme is an equally important consideration as the supply and distribution. Technically, a scheme can function most efficiently when it has a steady heat demand profile with few peaks and troughs. This is achieved by connecting a range of different types of customers from domestic

households, to commercial shops and offices, to larger and more constant heat users such as hospitals and swimming pools. Economically, the location of heat demand is also important. The high capital costs of a network are minimised by connecting to areas of dense heat demand. When heat demand becomes less dense the capital costs of the network can prevent the heat supply from being financially viable (for example, in rural or suburban detached domestic household areas). The risk of investing in the high upfront capital costs of a scheme can also be mitigated using heat demand, by securing heat supply contracts with key customers (preferably with long-term contracts for 10-20 years). These anchor load customers tend to be large heat users such as universities, shopping centres or hospitals, but can also be secured with large numbers of domestic connections such as in new-build housing developments. DH customers are usually charged in two parts for their heat supply; (1) through a set-standing charge which covers the capital costs and maintenance costs of the network, (2) for each unit of heat used by the customer (measured with a heat meter with a variable price according to the price of heat supply to the system).

2.2. The UK energy system and heat

Establishing a balance between the supply, distribution and demand-side for new DH schemes can be challenging and is highly dependent on the social, economic, and physical context in which a scheme is being developed. In this section we outline the context of the empirical focus of this thesis: the energy system of Great Britain.

Geographical focus of this thesis

The case study scope used in this thesis focuses on the context of DH within the boundaries of England, Wales and Scotland. Energy policy in Northern Ireland is devolved and is excluded from this study to simplify analysis and discussion.

Across England, Wales and Scotland, gas and electricity policy is a reserved power that remains under the responsibility of the UK Government. In recent years a new policy agenda for heat has emerged, aiming to drive decarbonisation of heat, including increasing DH development. Heat policy in Scotland is devolved to the Scottish Government, and the UK Government is responsible for heat policy in England and Wales. Where differences in the policy approach exist between Scottish and UK Government, they are highlighted in the discussions throughout the chapters.

Despite the complicated devolved responsibilities for energy across the nations within the UK, much academic, statistical and policy documents address the UK as a whole. The following sections outline historical and contextual factors that are relevant to Great Britain, although it has been necessary to draw on references that refer to the UK.

2.2.1. History of the UK energy system

Rüdig (1986) identifies links between the organisational structure of electricity supply institutions and the rate of uptake of DH since CHP formed an important heat source for many DH schemes in recent decades. Using the example of Germany, Rüdig demonstrated that development of DH was more likely where local-level organisations such as municipalities had retained a role as electricity supply utilities. Centralised electricity supply organisational structures, such as in the UK, created a significant obstacle (Rüdig, 1986). The structure of an energy system as a whole (for electricity, heating, and cooling) therefore plays an important role in enabling or hindering DH development.

Historically in the UK, the introduction of CHP into the electricity supply of an energy system was a strong driver for DH development. At the beginning of the twentieth century there were nearly 600 small-scale electricity suppliers in the UK owned by municipal utilities or funded through private capital (Thorp and Marvin, 1995). After the Second World War, in the context of fuel shortages and increasing electricity demand, the UK government nationalised the electricity sector in 1947 and set up the British Electricity Authority, which later became the Central

Electricity Generating Board (CEGB, 1957) (Lehtonen and Nye, 2009). Nationalisation of electricity at this point led to the development of large-scale centralised power plants. This change also ended local authorities' role in municipal-level energy supply, removing the presence of an actor in the energy system focused at the local level (Thorp and Marvin, 1995).

Under nationalisation, responsibility for energy system policy and organisation was given to industry managers at the British Electricity Authority. The social objectives of the Labour government at the time of nationalisation provided initial government support for CHP and DH technologies as part of an agenda to rebuild destroyed cities and to clear slums. However DH and CHP were viewed as challenging technically for balancing the grid as well as a potential drain on scarce capital investment funds (Russell, 1993). Although the Electricity Act had a specific provision that required the British Electricity Authority to 'investigate' options for CHP, investigations were done on BEA-imposed economic assessment terms and large centralised electricity plants were favoured over numerous smaller CHP plants integrated with DH networks. Strong lobbying from the gas industry also ensured that there was no subsidy for CHP projects which might compete with gas as the increasingly dominant heating fuel (Russell, 1993).

Alongside changes in electricity supply, changes were also taking place within heating provision. Increased use of gas central heating systems was leading to a steady fall in domestic sales of coal during the 1960s and 1970s. The National Coal Board saw DH as a way to retrieve parts of the domestic market and started competing for delivery of heat services to large customers such as local authorities and hospitals (Russell, 1993). However, there was a lack of knowledge and experience of how to install and operate DH, and projects could not compete financially with cheap natural gas. "Unreliability, technical failings and costly repairs; high charges and accumulating debt; the additional tasks and problems for housing managers in administering the only utility not vested in another state body; and lack of consumer control and of an acceptable heat meter all combined to engender widespread dislike of DH among consumers and authorities" (Russell, 1993, p.43).

Margaret Thatcher's Conservative government was elected into power in the late 1970s with an agenda of strong liberalisation after the severe economic downturn experienced after the oil crisis (Lehtonen and Nye, 2009). The energy sector was privatised in the late 1980s, firmly steering it away from government-led objectives towards profit maximisation for shareholders, in the context of a highly centralised electricity system with heating mainly provided through individual gas-boiler central heating systems (Lehtonen and Nye, 2009).

Today, the UK energy system continues to be highly centralised with a liberalised energy market and a high penetration of natural gas networks for heat supply to buildings (Hawkey and Webb, 2014). An independent energy regulator, OFGEM, has a regulatory approach that minimises public sector intervention in the daily operation of electricity and gas networks and encourages market-based competition. In general, the UK Government's market-led approach to energy policy seeks to be technology and fuel neutral in order to let the market select the most effective solution (Bolton and Foxon, 2013).

2.2.2. Heat policy and district heating in the UK

Heat supply currently accounts for the largest proportion of final energy-consumption (42%) and contributes 38% of the UK's carbon emissions (DECC, 2013c). Domestic sector heat demand was responsible for 25.9% of the total UK energy consumption in 2011, the majority of which is generated using natural gas (65%) with the rest coming mainly from electricity and a small proportion from others such as oil, coal and wood (DECC, 2013c).

The publication of the UK's first Strategic Framework for heat reflected the growing recognition of the importance of decarbonising the heat sector, whilst balancing this with priorities for affordable and resilient energy supply (DECC, 2012a). This policy document highlighted an important role for DH amongst a mix of technologies needed to meet future low carbon heating demand. An action plan for heat, published a year later in 2013, suggested that 14 – 40 % of heat demand could be supplied through DH by 2050 (DECC, 2013c). Even the lower end of this scale signifies large-scale change from the current energy system. Data on the levels of DH within Great Britain is not yet readily available. At the last

approximation in 2009, only 2%[2] of the heat demand was delivered by DH in the UK as a whole (Poyry and Faber Maunsell, 2009).

The UK Government has introduced new policy support measures aiming to develop low carbon heating technologies including DH, the main one being the Renewable Heat Incentive (RHI). The non-domestic RHI (Ofgem, 2015), introduced in 2011, is designed primarily to incentivise renewable heat uptake in the industrial, commercial and public sectors, but is also applicable to heat generation for DH supplying domestic properties. The Energy Company Obligation (ECO) – a scheme which obligates larger suppliers to deliver energy efficiency measures to domestic premises in Britain – has also been used to support DH development (DECC, 2013a), although this has been subject to policy change over recent years and is likely to cease to operate in its current form from April 2017. Local planning policies have been used at the local level to encourage, and in some cases require, DH development in new build developments. For example, in the Greater London area, borough councils have used strong planning policy (supported by planning guidance from the Greater London Authority (GLA)) to require new developments to install DH where feasible as a condition of planning permission.

The dominance of gas and electric heating systems means that there is currently no formal regulation of heat supply in the UK covering issues such as customer protection or technical standards. Regulation has been limited to gas and electricity markets. Recognition of the need for such regulation is growing and debate is on-going over the best way to do this. For example, the Scottish Government established a Special Working Group of its Expert Commission on District Heating to consider potential regulatory frameworks for district heating and provide advice to Government (Scottish Government, 2015). Although there is no regulated customer protection, a voluntary industry-led customer protection scheme was launched in November 2015 (Association of Decentralised Energy, 2015). DH operators can take part in the scheme voluntarily, which seeks to ensure a common standard in the quality and level of protection given by heat

[2] Statistics on DH are not published regularly and it is likely that this number has increased since 2009.

supply contracts and offers heat network customers an independent process for settling disputes. However, it does not cover any aspect of heat price.

2.2.3. A new role for local authorities in the UK energy system?

Internationally, municipal governments are highlighted as having an important role in DH development for countries with a significant proportion of DH embedded in their energy system (Grohnheit and Gram Mortensen, 2003; Riahi, 2015). They have either developed systems themselves or created conditions for other actors to successfully develop them with use of policies that enabled long-term financing of projects, using measures such as financial underwriting to overcome the short-termism of global financial systems (e.g. Denmark, Sweden, Germany) (Ericsson, 2009; Hawkey et al., 2013). In an analysis of the Danish approach to heat policy, Chittum and Ostergaard (2014) identify local strategic planning exercises and powers to enforce them as critical to the success of Danish DH.

In the UK, a potential role for local authorities is recognised in the UK Government's strategic framework for heat:

> *"Heat networks can be integrated with local authority plans for urban growth and regeneration aimed at tackling social deprivation and environmental issues such as air quality. They can also be part of an integrated low carbon system as already seen in some European cities."* (P. 59, DECC, 2012a)

Local authorities hold local planning powers which can be used to influence connection of new developments to DH networks. They can also use their own estate (often containing large office blocks, leisure centres, social housing, etc.) as anchor loads of heat demand to reduce the risk associated with pay back times on scheme investments.

In practice, UK local authorities often face constraints on resources and capacity that make it challenging to take on a new planning role within the energy system (BRE et al., 2013; CAG Consultants, 2015). Local authority budgets and staffing levels have suffered significant cuts in recent years and they face constraints in terms of knowledge, experience, and staff time. As a result, their financial resources are limited for procuring much-needed feasibility studies and other

consultancy services, legal advice, and providing the significant upfront capital costs of networks (BRE et al., 2013). Bale et al. (2012) also point out that local authorities face financial and structural barriers that prevent them taking on a role in strategic energy planning, including the need to work across multiple departments (planning, waste, finance, legal, and procurement) simultaneously, contrary to the way their governance systems usually function.

In England and Wales, the Heat Network Delivery Unit (HNDU) was set up within the UK Department for Energy and Climate Change (DECC) in 2013 to support local authorities in taking on a new facilitating role for DH development. This unit seeks to tackle the issues of 'capability and capacity' faced by local authorities by offering guidance, support and funding to commission studies by consultants to feed expertise into local authorities (DECC, 2014). In Scotland, a distinct programme of support exists through the Scottish Heat Network Partnership which offers local authorities access to expertise from existing Scottish organisations including commercial, legal and technical advice, and funds consultancy work where necessary. The number of local authorities that are actively considering options for DH is now growing steadily (for example, 115 local authorities have undertaken some kind of DH development activity under the HNDU funding programme (CAG Consultants, 2015)) and these support mechanisms are beginning to encourage the use of heat maps, energy masterplanning and stakeholder engagement to overcome the early hurdles of DH project development. However, as yet most of these projects have not reached the delivery stage and DH development has rarely become part of the mainstream business of local authorities.

2.2.4. Fuel poverty and district heating

Issues of fuel poverty are often included in discussions of heat supply options in the UK. Fuel poverty is the term used to represent the concept of a household being unable to ensure adequate energy services within its living space, and space heating is often seen as a particularly important part of this due to its implications for people's health. In the UK, it was estimated that 10.9% of households were

living in fuel poverty[3] in 2011 (DECC, 2013b). Its causes are often described as a combination of three main factors: low income, poor energy efficiency and high fuel prices (Ürge-Vorsatz and Tirado Herrero, 2012), the latter being the dominant driver (Jenkins et al., 2011).

There is increasing recognition of the potential for some DH projects to contribute to fuel poverty reduction alongside carbon emissions reduction, under the right governance and business models (Walker, 2008; Andrews Tipper, 2013; DECC, 2013c). Its use of waste heat and efficient generation technologies result in lower fuel consumption and therefore lower energy costs. Individual consumers are not responsible for the maintenance of the delivery system; an aspect which early research suggests is favoured by consumers since it removes households' vulnerability to technical problems and unforeseen costs (DECC, 2013c). Some local authorities have already begun to create heat networks with the dual aim of reducing fuel poverty and reducing carbon emissions (e.g. Webb, 2015; UKDEA, 2013).

Example: Aberdeen Heat and Power

After an energy appraisal of Aberdeen's housing stock in 2002, the city's multi-storey blocks of flats were identified as having particularly poor energy performance and were classed as difficult to heat with a reliance on electric heating systems that were expensive for residents to run. Many of the residents lived in fuel poverty and could not afford to heat their homes sufficiently, resulting in damp and poor health conditions (Aberdeen Heat and Power, 2012). DH was identified as the lowest cost solution in the long term. The city council created an arms-length, not-for-profit company called Aberdeen Heat and Power to set-up and run DH around the city with the explicit aim of reducing fuel poverty for the residents of Aberdeen.

A number of DH projects were developed using gas-fired CHP as a heat and electricity source, focusing on multi-storey social housing flats, and connecting to other nearby public sector-owned buildings such as swimming pools. The

[3] This figure is based on the updated UK Government definition of fuel poverty: 'Low income high costs'.

company was able to make use of grants and 0 % interest loans to cover parts of the capital costs of schemes, and as a result, the projects achieved typical financial savings on energy bills for the residents of 40-50% per month, making a significant impact on fuel poverty levels and improving the desirability of the homes to residents (Aberdeen Heat and Power, 2012).

There is potential to both reduce fuel poverty and carbon emissions using DH. However, this is dependent on how the individual projects are developed and governed as well as their physical characteristics. The physical context, governance and business models still vary greatly from project to project and not all schemes are able to offer such significant cost reductions for customers.

2.3. Choice and scope of the case study

The case study of DH in Great Britain has been selected as a useful empirical example with which to explore challenges of governing niche processes to drive low carbon transitions. As a researcher based in Great Britain, selection of this case study made the practicalities of data collection easier to manage. In addition, it offers an example of a low carbon technology at the early stages of deployment. Existing DH networks within the UK have come about due to specific local circumstances (Hawkey et al., 2013), which can be conceptualised as a form of local niche. Similarly, the majority of policy measures and DH development activities in the UK are focused on forms of niche creation and development. This early stage of DH development within the energy system of Great Britain makes it a useful case study specifically for exploring aspects of niche empowering processes and actor agency.

This case study therefore presents a particularly challenging example of barriers that face many low carbon technologies. As a technology, DH connects all three functional aspects of the energy system: energy generation, distribution and demand. Its nature as a local infrastructure technology also means that issues such as high capital costs and investor risk perceptions, as well as lack of institutional support or strategic coordination are particularly strong. Furthermore, the history of Great Britain's energy system, with energy nationalisation, followed by

privatisation and liberalisation, has left it with a highly centralised system and a market-led approach to introducing new low carbon technologies (Bolton and Foxon, 2013). This culture of minimal government intervention also provides an interesting case study to explore the role of actors from across the private, public and civic sectors; going beyond government-led policy and instead considering cross-sector governance arrangements.

2.4. Existing research on district heating

Applied research into DH has increased in recent years, particularly across Europe, as recognition of its potential role in low carbon heat delivery has grown. In this section, an overview of the relevant research landscape is given, first exploring studies using a techno-economic focus, followed by studies with a socio-political and governance focus. Gaps in the applied literature are highlighted in section 2.4.3.

2.4.1. Techno-economic approaches to DH research

Techno-economic approaches to DH research have been used to explore a wide-range of research questions, considering problems of economic and environmental optimisation (Keirstead and Calderon, 2012; Finney et al., 2012a; Finney et al., 2012b; Keirstead et al., 2012), modelling to fill in data gaps (Connolly et al., 2014), and future scenarios to inform strategic energy planning (Poyry and Faber Maunsell, 2009; Connolly et al., 2015; Energy Technologies Institute, 2012). Techno-economic modelling of DH can prove challenging as models need to take into account spatial dimensions such as distances and capacity of potential heat supply sources, heat demand density, geographical obstacles such as railway lines or rivers, and existing schemes that have the potential to be expanded. In the UK (and many countries across Europe), relevant and accurate data to inform these types of analysis are often not collected, or are considered commercially sensitive, and therefore need to be estimated with modelling or proxy-indicators (Connolly et al., 2014; Finney et al., 2012b). Despite these challenges, techno-economic analyses continue to play an important role in informing the decisions of policy makers and local delivery actors through local heat mapping exercises, assessing

financial viability of projects, and setting of policy targets for DH uptake (Scottish Government, 2012; Scottish Government, 2015; DECC, 2013c).

The assumptions within techno-economic analyses are necessarily based upon factors shaped by the socio-political context, and they can have a significant impact over results. For example, modelling exercises considering future scenarios for DH-levels in the UK gave significantly different outputs, from up to 14% (Poyry and Faber Maunsell, 2009), to 43% (Energy Technologies Institute, 2012), to 70% (Connolly et al., 2015) of heat demand delivered by DH by 2050. The outputs of these various exercises depended upon the assumptions and selection criteria applied by the researchers about the context in which DH is being installed. The highest scenario (Connolly et al., 2015), suggesting a penetration of 70% of heat demand in 2050 assumed that the lowest cost, low carbon heating technology would be installed regardless of financial viability, whereas the Poyry and Faber Maunsell scenario (2009) considered financially viable schemes under a change in market and regulatory framework, including a carbon price and "de-risked" cost of capital. The wide variations between these results demonstrate the importance of understanding the socio-political drivers and barriers to DH introduction, as well as the techno-economic aspects.

2.4.2. Beyond techno-economic research on DH in the UK

The socio-political dimensions of DH can make it a particularly complex technology to develop and embed into an energy system. For large-scale schemes it requires cooperation and coordination between numerous actors with differing objectives and circumstances (Summerton, 1992). In contexts where there is little existing DH, it is often perceived as a high investment risk because of the high upfront capital costs of the DH infrastructure, lack of knowledge and skills to support its installation, operation and maintenance, and uncertainty on the demand side around public opinions and trust of the technology. Institutional barriers can also play a role, such as unsupportive regulatory frameworks or the absence of the necessary business models (Riahi, 2015; BRE et al., 2013; Hawkey, 2012).

Research considering socio-political aspects of DH development within the UK context is still relatively limited. Studies to date have highlighted the barriers

posed by a highly centralised institutional context of the UK energy system (Hawkey, 2012; Hawkey et al., 2013; Webb, 2015; Bolton and Foxon, 2013). In a historical account of the lock-out of DH and CHP from the UK energy system, Russell (1993) described the impact of nationalisation of energy, resulting in a corporatist electricity authority which favoured large centralised systems over CHP and DH. After privatisation and market liberalisation, the impact of the UK government's neo-liberal policy approach also worked against introduction of DH, with a reluctance to intervene in energy markets and a systematic weakening of local authority powers and resources (Bolton and Foxon, 2013).

Where schemes have been successfully developed within the UK, Hawkey et al. (2013) described their success as "irreducibly bespoke and tied to local context, multi-organisational networks of expertise, bridging local knowledge, governments and financial and energy markets" (p.29). They highlight a reliance on social capital to overcome barriers. In an example of the arms-length municipal energy company, Aberdeen Heat and Power, Webb (2015) demonstrates a process of “innovation through improvisation”, where actors influenced and responded to their specific local circumstances to create a political convergence of fuel poverty and climate change issues. This enabled them to redefine Aberdeen local authority’s assessment of ‘best value’ investment to mean “lowest cost in use” for local residents, thereby providing an accepted justification for using DH. Both studies suggest that embedding of DH into the UK will require a shift from top-down command and control planning to "centrally established supportive standards and incentives and developed municipal powers" (p.30, Hawkey et al., 2013).

2.4.3. Gaps in the socio-political literature on DH in the UK

The existing studies have provided a rich foundation for exploration of governing a DH transition in the UK, but the limited number of socio-political studies to date means that there are still a number of key gaps in the literature. The studies outlined above have primarily explored characteristics for successful DH delivery. Although they begin to discuss implications for governing a transition to wide-spread uptake of DH, they do not explore specific measures in detail. This presents an opportunity for this thesis to contribute to a gap in the applied, socio-political

literature on DH in the UK, to explore measures for governing a transition to DH. By considering the role and perspectives of actors involved in a broader range of projects – not only the successful ones - the thesis seeks to add to understanding of how to move the UK beyond one-off project successes to systemic delivery of DH in strategic locations.

2.5. Chapter summary

This chapter has introduced and discussed the choice of case study. It has set out the key characteristics of DH as a low carbon technology, alongside relevant aspects of the context in Great Britain. In addition the chapter has considered gaps in the applied, socio-political literature on DH in the UK. The thesis particularly seeks to make a contribution to this applied literature on governing a transition to DH, as well as drawing policy lessons for actors in Great Britain. Chapter 9 brings together the results of each of the empirical chapters (chapters 5 – 8) to discuss the contribution of the thesis as a whole.

Next, chapter 3 considers the existing theoretical literature and presents the relevant areas that are used to inform analysis of empirical data from the case study. It presents a critical review of the literature on governing socio-technical transitions and highlights existing gaps in this body of literature. Finally, it sets out the theoretical approach used as the basis of analysis for answering the thesis research questions and highlights areas of theoretical contribution made by the thesis.

3. Theoretical approach

3.1. Introduction

The increasing awareness and urgency surrounding challenges such as mitigating climate change has led to an increased research interest in how it might be possible to bring about a transition to a more sustainable global society. Of particular relevance to the focus of this thesis on governing for a transition to district heating (DH), a number of theories have developed around how technology innovations are introduced and diffused. The empirical analysis draws on theories of socio-technical transitions, which consider the interaction between the social and the technical dimensions of a system. There is a range of theory that has been developed in this area using similar concepts but placing different lenses over the process of transition (Geels, 2002; Rip and Kemp, 1998; Bergek et al., 2008; Foxon, 2011). Due to the early stage of development of DH in the case study, particular focus is given to the role of protected niche spaces in enabling actors to govern socio-technical transitions.

This chapter presents a critical review of some of the key parts of the literature on transitions. Section 3.2 defines the critical concepts used within this body of literature: socio-technical systems, regimes, and transitions. Section 3.3 presents a critical review of theories relevant to questions of governing transitions. Finally, the chapter sets out and justifies the theoretical approach used throughout the thesis to inform analysis.

3.1.1. Key concepts in socio-technical transitions

Socio-technical systems

The concept of a **socio-technical system** considers the interaction and relationship between the social and technical dynamics of the world. Geels described a socio-technical system as:

> "The linkages between elements necessary to fulfil societal functions (e.g. transport, communication, nutrition). […] They consist of artefacts, knowledge, capital, labour, cultural meaning, etc." (p.900, Geels, 2004)

The socio-technical system is an analytical concept and can therefore be applied with different scopes and geographical scales within empirical examples.

This concept has been explored by numerous researchers as part of endeavours to gain a greater understanding of the complex process of change that takes place when a technological innovation enters into widespread use (Kemp et al., 1998; Geels, 2004; Bergek et al., 2008; Foxon, 2011). The concept has been developed from a range of theories (sectoral innovation systems, technological systems and large technical systems) which recognise systems as a web of interlinked elements (Geels, 2004). The system is not static, but instead evolves over time.

Socio-technical regimes

Another important theoretical concept used throughout this thesis is the socio-technical regime. Drawn from the literature on socio-technical transitions (Rip and Kemp, 1998; Geels, 2004), the socio-technical regime is used as a way to understand the dynamics of socio-technical systems over time and makes an analytical distinction between socio-technical systems and the actors, rules and institutions within them. The rules and institutions of the socio-technical system provide a form of coordination for activities within the system. Interrelated rules and institutions, such as for policy, users and markets, politics, or science, form rule-regimes. These regimes are autonomous with their own rule-sets, but also interdependent and influenced by each other. Together these different elements form sub-regimes of an overall **'socio-technical regime'** for a given socio-technical system.

> "Socio-technical regimes can be understood as the 'deep structure' or grammar of socio-technical systems." (p.905, Geels, 2004)

Different elements of a socio-technical system are understood to co-evolve over time, guided by the rules of the socio-technical regime. Changes in one aspect of the system shape the socio-technical system as a whole (Geels, 2004).

Actors undertake activities within the socio-technical system in order to improve their situation. This could be to improve the efficiency of existing technologies and processes, or to respond to tensions and challenges within the system. The deep 'structure' of the socio-technical regime influences the types and extent of changes

that actors make. The introduction of an innovation into the system when it does not fit within the existing set up of the socio-technical regime is challenging. When changes occur in elements of the system, they take place incrementally with a '**path-dependency'**. This creates **stability** in socio-technical systems. Geels argues that these paths are shaped by the rules of the regime, actors organisational networks, and physical / material aspects of the system (Geels, 2002; Geels, 2004):

The cognitive rule sets of the socio-technical regime define which issues are seen as important and focus development on particular skills and knowledge. The rules also create expectations on actors about how it is appropriate to behave within the system, and can prevent actions that fall outside of these rules. These cognitive rules are often further reinforced through the development of regulative rules, such as laws and contracts, which can further limit actors' choices for action.

Actors form networks within the socio-technical system that support particular actions. These networks build up organisational capital as they become more established and can develop commitments and vested interests in the existing socio-technical system that prevent alternatives developing. Physical and practical manifestations of the existing socio-technical system can create further barriers to change, (for example, in terms of existing infrastructures, or economic investments in the existing technologies).

This stability creates **lock-in** to a particular socio-technical system and limits the type of change that can take place within the system. Introducing radical innovations that do not 'fit' into the existing system requires fundamental changes to the socio-technical regime and its surrounding system.

Socio-technical transitions

A '**transition'** is the term used to describe the complex process of deep structural change to a socio-technical system. It involves "alterations in the configurations of technology, policy, markets, consumer practices, infrastructure, cultural meaning and scientific knowledge" (p.24, Geels, 2011). Interest in understanding socio-technical transitions has grown with awareness of global sustainability challenges. Finding solutions to 'wicked' problems such as climate change, over-consumption of natural resources and environmental degradation will need radically altered

socio-technical systems (Markard et al., 2012). The pressing need to actively shift to more sustainable systems has stimulated a research and debate into how re-configuration of socio-technical systems could be actively governed through mechanisms of policy or wider actions (Kemp et al., 1998; Kemp et al., 2007).

3.2. Theoretical approaches to governing transitions

There are a number of different proposed theoretical approaches that can contribute to understanding of how regime change might be governed. These approaches have been designed with different purposes in mind, from frameworks to structure academic analysis for understanding the causes and dynamics of regime change (Geels, 2004), to practical methods for informing policy decision making processes (Loorbach and Rotmans, 2006).

The different theories on governing transitions are a source of much debate. Key aspects of these debates focus on the causes of regime change; the capacities of different actors to influence change; and which actors are responsible for governing a transition. Some scholars question whether it is even possible to govern change in a complex socio-technical system, especially given that the actors seeking to govern change are acting from within the system itself and affected by the incumbent regime (e.g. Shove and Walker, 2007).

In the rest of this chapter, key aspects of the socio-technical transitions literature are presented and discussed in relation to their relevance for addressing the thesis research question:

> What lessons can be drawn from a case study of DH development in Great Britain for actors seeking to govern a transition to DH as part of a low carbon energy system?

A comprehensive review of all the literature in this area is not provided here. Instead theories and approaches that are deemed to be particularly prominent and relevant are discussed to give a sense of the different ways that systemic change can be conceptualised and understood. First, the role of niches as a mechanism for stimulating regime change are discussed, including the strategic niche

management approach, the role of intermediaries, and the concepts of niche shielding, nurturing and empowering processes (section 3.2.1 – 3.2.4). Then two broader conceptual frameworks aimed at analysing the broader dynamics of regime change are discussed – the multi-level perspective and the co-evolutionary framework (section 3.2.5 and 3.2.8). These complementary, but distinct, approaches encourage different analytical foci and as a result can offer different contributions to understanding complex systems change. Further developments in the multi-level perspective and socio-technical transitions are also presented on regime resistance (section 3.2.6) and questions of geography in transitions (section 3.2.7). Following this, theories on technology innovation systems and transitions management are discussed as examples of applied theories on governing transitions aimed at policy makers (section 3.2.9 and 3.2.10). These various approaches are discussed in terms of their relevance for analysis of the case study of DH in Great Britain – an example of a technology in the early stages of transition where actors are seeking to apply the technology in many locations for the first time.

3.2.1. Niches as mechanisms for stimulating regime change

Niches are a key concept within socio-technical transition processes, and form a significant focus in this thesis (Kemp et al., 1998; Kemp et al., 2007). Niches are 'protected spaces' within a socio-technical system where innovations can develop away from the selection pressures of the incumbent regime. The protection provided by a niche enables demonstration and refinement of an innovation. They also give actors an opportunity to learn relevant skills and build surrounding actor networks necessary for successful application of an innovation. Niches are not necessarily defined by a geographical area (although they can be) (Geels, 2011), but instead might refer to the distributed application of an innovation e.g. use micro-generation across an energy system.

The socio-technical transitions literature views niches as playing an important role in enabling a wider transition to take place (Kemp et al., 1998; Geels, 2004; Smith and Raven, 2012). Theoretically, they enable development of an innovation until it is at a stage where it can be diffused within the wider regime. As a result, they have received a great deal of attention in the literature on governing socio-technical transitions – especially for sustainable transitions where many technologies have been at the early stages of application and diffusion (Smith and Raven, 2012). The following three sections present various aspects of the transitions literature related to the role of niches in transitions: Strategic niche management, the role of intermediary actors in niche development, and the concepts of niche shielding, nurturing and empowering processes.

3.2.2. Strategic niche management

Strategic niche management was one of the early theories of governing transitions that focuses on the role of niches in driving transitions. Kemp et al (1998) defined it as:

> "The creation, development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology". (p.186, Kemp et al., 1998)

In a later review of the developing literature on strategic niche management, Schot and Geels (2008) summarised the theory into three activities that were required for development of a successful niche:

1. Articulation of expectations and visions for the innovation – these needed to be shared by actors across the niche; be specific enough to give guidance on actions to support the innovation; and be backed up by practical, on-going projects to iterate and improve on initial expectations and visions.
2. Development of social networks to support the technology – the social networks should include multiple kinds of stakeholders who are able to influence and mobilise commitment and resources from within their own networks.
3. Learning processes over multiple dimensions (both technical and social) – learning processes should endeavour not just to achieve first-order learning (i.e. "the accumulation of facts and data") but to also achieve second-order learning that allows changes in "cognitive frames and assumptions" (p.541, Schot and Geels, 2008).

Strategic niche management is not carried out by just one actor or institution, but is instead a "collective endeavour" of multiple actors (Kemp et al., 1998) who steer the process from within the niche (Schot and Geels, 2008). Kemp et al. (1998) highlight an important role for government in the process to steer action in the direction of the collective good, and away from being dominated by the special interests of particular actors or institutions. However, this focus on government actors has been cautioned in later studies. Smith (2003) and Hodson and Marvin (2010) both point out that governments are often deeply embedded in the existing regime and so tend to support incremental innovations rather than encouraging radical ones. A study by Lovell (2007) also supports this view. In her work, Lovell applies strategic niche management to the case of low energy housing in the UK to show how privatisation of many of the delivery sectors in this area means that the power that government has to affect niche development has diminished greatly. Instead niche development came about through the cooperation and actions of multiple stakeholders outside of government. Recognition of the need for involvement of multiple stakeholders and sectors, and that niche development is

not simply a process that can be led by government is an important new dimension of analysis when considering strategic niche management.

This recognition that 'governing' of transitions is a process of cooperation and interaction between multiple stakeholders is important for addressing the research questions within this thesis. This is discussed further in section 3.3 where the theoretical approach of the thesis is set out in more detail.

Local and global niches

Geels and Deuten (2006) developed the concept of niches further by introducing a distinction between '**local'** and '**global'** niches. Experiments with the same type of innovation may take place in multiple niches with different local contexts. Each of these niche spaces is a 'local' niche, and collectively they form a 'global' niche. Over time, experiences and learning from local niches can be shared and, where possible, aggregated to form a collective knowledge about the innovation at the global niche level (see figure 4). Geels and Deuten (2006) argue that this process may "gradually result in the stabilisation of a global technology trajectory for the innovation" (p.275). They recommend that policy should pay greater attention to learning processes between local niches and highlight an important role for 'intermediary' organisations in facilitating knowledge sharing and aggregation.

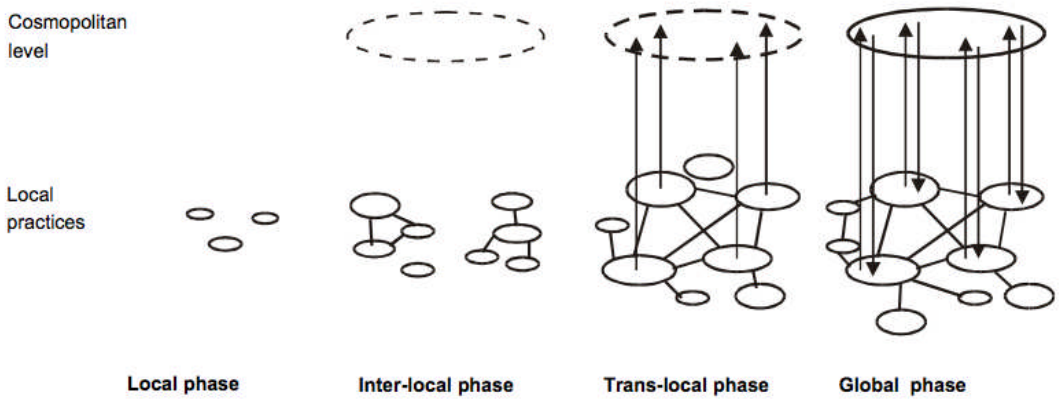

Figure 4: Phases in development of collective technological knowledge (Source: Geels & Deuten (2006), p.269)

3.2.3. Intermediaries

The concept of '**intermediary'** actors is drawn from innovation studies, where it is defined as:

> "Actors who create spaces and opportunities for appropriation and generation of emerging technical or cultural products by others who might be described as developers and users" (p.296, Stewart and Hyysalo, 2008).

In the context of socio-technical transitions, the definition of intermediaries is broadened to consider socio-technical innovations as the focus of intermediaries' work (including facilitating learning processes, building relationships and mediating between different actor interests and priorities), rather than only 'products' (Geels and Deuten, 2006; Hodson et al., 2013). Kivimaa et al. (2014) explores intermediary actors in more breadth and specifically their role in strategic niche management. They find that intermediaries can contribute to all three of the strategic niche management's processes (Schot and Geels, 2008), and they also note their potential to go beyond internal niche creation to contribute to systemic change for a socio-technical transition. Chapter 7 focuses on the role of intermediaries within socio-technical transitions for DH, and a detailed literature review on intermediaries is outlined there.

3.2.4. Niche shielding, nurturing, and empowering processes

The final section of literature on the role of niches presented in this chapter focuses on the properties of niches. Smith and Raven (2012) argue that previous literatures on niches have failed to systematically interrogate niches as a concept, and they distinguish between three distinct functions that they can perform: 'shielding', 'nurturing' and 'empowering':

Shielding processes act as a form of protection for an innovation so that learning and development can take place away from the full pressures of the regime. This may take the form of 'passive' shielding, where a niche is naturally created thanks to contextual circumstances such as an off-grid area of the energy system. 'Active' shielding uses active measures to shield the niche, for example tax incentives or subsidy, which shield the technology from the market environment. Multiple forms of protection will often be required to offer an effective shield from the resistant dimensions of the incumbent regime (Smith and Raven, 2012).

Nurturing processes support actors to learn and develop the skills, networks and capacities required to be able to apply an innovation (Smith and Raven, 2012). The

functions of strategic niche management (discussed in section 3.2.2) are examples of how such processes might be supported.

Empowering processes act to translate practices from the niche into the wider regime, to enable an innovation to be applied outside of niche spaces. The processes are iterative and can involve multiple actors (Smith and Raven, 2012). Smith (2007) describes the activities that enable empowering processes to take place as 'translations' of niche rules and practices to enable some form of incorporation into the socio-technical regime. Similar to the typology of socio-technical transitions pathways developed by Geels (2007), the presence of tensions within the incumbent regime are important enablers of successful translation processes, where actors can exploit tensions in the incumbent regime to argue for change or present a solution in the form of their innovation. Smith & Raven (2012) highlight two distinct types of empowering processes:

> **'Fit and conform'** processes seek to enable an innovation to compete within the selection environment of the incumbent regime. This requires learning processes within the niche to enable innovations to develop to an extent where they can function within the incumbent regime, through both first order and second order learning[4].
>
> **'Stretch and transform'** processes seek to alter the practices and norms of the incumbent regime sufficiently to enable the innovation to be applied without the need for protection or adaptation.

Context, power and agency are important determinants of the influence or success of empowering processes (Smith, 2007; Smith and Raven, 2012). Activities to support niche empowering processes are shaped and determined by actors' access and commandment of "material and non-material resources, and collective action" (p.1031, Smith and Raven, 2012). They identify the importance of discursive strategies and narratives as a mechanism for actors to mobilise these resources,

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[4] Smith (2007) refers to first order and second order learning processes within niches. First order learning is described as learning about the "immediate, surface features" of a socio-technical innovation, whereas second order learning "questions the values and assumptions that frame the socio-technical configuration" of an innovation.

actor networks, and to influence the regime context. Global niche actors (see section 3.2.2, Geels and Deuten, 2006) play an important role because of their ability to draw on experiences and evidence from local niches and adapt their messages for key actors. For 'fit and conform' empowering processes, embedded regime actors are a key audience, whereas for 'stretch and transform' empowering processes, a key audience are actors who are lobbying for institutional reform already. Smith and Raven (2012) highlight three types of characteristics they expect to see in narratives aiming to empower innovations:

1. Positive expectations about a future with widespread uptake of the innovation and niche practices
2. Arguments for specific institutional reforms that would favour the niche innovation
3. Criticisms of the incumbent regime, to highlight tensions where the innovation can provide a solution.

Smith and Raven (2012) emphasise how empowering processes are likely to be messy, and full of competing narratives from different niche and regime actors. Translation processes are two-way and iterative, not just translating practices from the niche into the regime, but also resulting in adapting the practices of the niche according to translations from the regime (Smith, 2007). Translations of niche practices do not necessarily take all aspects of the original innovation. For example, Smith (2007) illustrates how the process of empowering organic food supply resulted in only certain aspects of the original sustainable organic food niche being translated and adopted by the regime (i.e. large-scale organic production for distribution and supply by multi-national supermarkets rather than small-scale, local organic farming distributed by local shops). This left the niche actors within the study unsatisfied with the loss of many of their original sustainability objectives and led to the adoption of alternative translation activities focusing on local and seasonal food (Smith, 2007). Further empirical studies of niche processes have explored various issues such as niche creation for transport innovations, energy innovations and agriculture innovations (e.g. Truffer et al., 2002; Raven, 2005).

Smith and Raven (2012) note that the socio-technical transitions literature is least developed on the subject of niche empowering processes, despite researchers' interest in niches being driven by their potential for catalysing transitions in the long term. Empowering processes and the concepts of translation narratives and agency are explored in more detail in particular in Chapters 8 and 9. A theoretical contribution of this thesis is therefore to add to understanding of how empowering processes take place and might be governed.

Criticisms and further developments of theories on niche processes in transitions

There have been various criticisms and calls for theoretical and empirically-based development of the literature on niches, particularly regarding empowering innovations and stimulating reconfiguration of the socio-technical regime. For example, in a review of empirical studies applying strategic niche management theory, Schot and Geels (2008) argue that many cited case studies were not successful at stimulating deep socio-technical change. The presence of niches enabled first order learning such as technical adjustments or development of delivery processes, but rarely enabled second order learning such as re-framing of a problem or shifting understanding of how an innovation should be valued (Schot and Geels, 2008). They recognise that the process of niche creation and innovation development is not sufficient to stimulate a regime transformation on its own. Broader forces and pressures across the socio-technical system are needed.

Hargreaves et al. (2013) cautions that diffusion or scaling up of an innovation is not always desired by actors in a niche. They highlight the diversity of visions and contexts in community energy examples, and argue that for some local, grassroots innovations it is more appropriate for intermediaries to focus on innovating within a local space, rather than aiming to scale up and alter the socio-technical regime. Work by Seyfang and Smith (2007), also focusing on community energy groups, distinguishes between 'strategic' niches which seek to scale up innovations to become part of the regime and 'simple' niches which instead seek to enable or protect space for grassroots innovations. Studies of sustainable transitions need to consider whether strategically managing niche spaces is appropriate.

3.2.5. The multi-level perspective

Niche processes are an important part of governing and understanding transitions, but the literature recognises that these processes are not sufficient to catalyse regime changes on their own (Smith et al., 2005; Kemp et al., 2007). The wider context and dynamics of the system have an important role as well.

The multi-level perspective is an analytical framework that seeks to conceptualise the influence of the wider system context within transitions. It is an analytical framework and seeks to add to understanding the transition process, rather than to provide an approach to governing transitions (Geels, 2011). The framework describes socio-technical regime reconfiguration taking place at multiple levels (macro-, meso- and micro-levels).

At the meso-level, the actions of social groups of actors enable reproduction of the socio-technical regime along relatively stable pathways. The internal dynamics of sub-regimes occasionally create internal tensions within the overall socio-technical regime, which present opportunities for a transition (Geels, 2002).

At the macro-level, pressures from the external landscape shape the socio-technical regime. The landscape represents "an external context that regime actors cannot influence in the short run" (Geels and Schot, 2007) such as global population dynamics, wars or political philosophies. Dynamics at the landscape level do not directly impact on the regime, but are perceived and interpreted by regime actors who adapt to these influences (Geels, 2011). The landscape can be both destabilising and stabilising to a regime. For example, influences such as climate change can act as a destabiliser, enabling low carbon technologies to establish and begin to reconfigure the regime. Conversely, landscape trends such as individualisation within societies could act as a stabiliser to a regime already configured towards personal car-use (Geels, 2011).

At the micro-level, actors experiment and develop innovations within niches; a process outlined in detail in the preceding sections. Over time, niche-level innovations can establish their own socio-cognitive rule sets and stabilise in a dominant design, making them a stronger pressure on the socio-technical regime.

Niche innovations use 'windows of opportunity' provided by tensions within the regime to begin a reconfiguration process and break into the regime.

Geels (2002) represented the transition processes pictorially (Figure 5). At the meso-level of the regime, thin arrows represent the relatively stable co-evolution of 7 sub-regimes. Shorter arrows represent internal regime tensions. Pressures from the macro- and micro-levels then act on the socio-technical regime trajectories, and altered regime configurations allow innovations to diffuse into the socio-technical system.

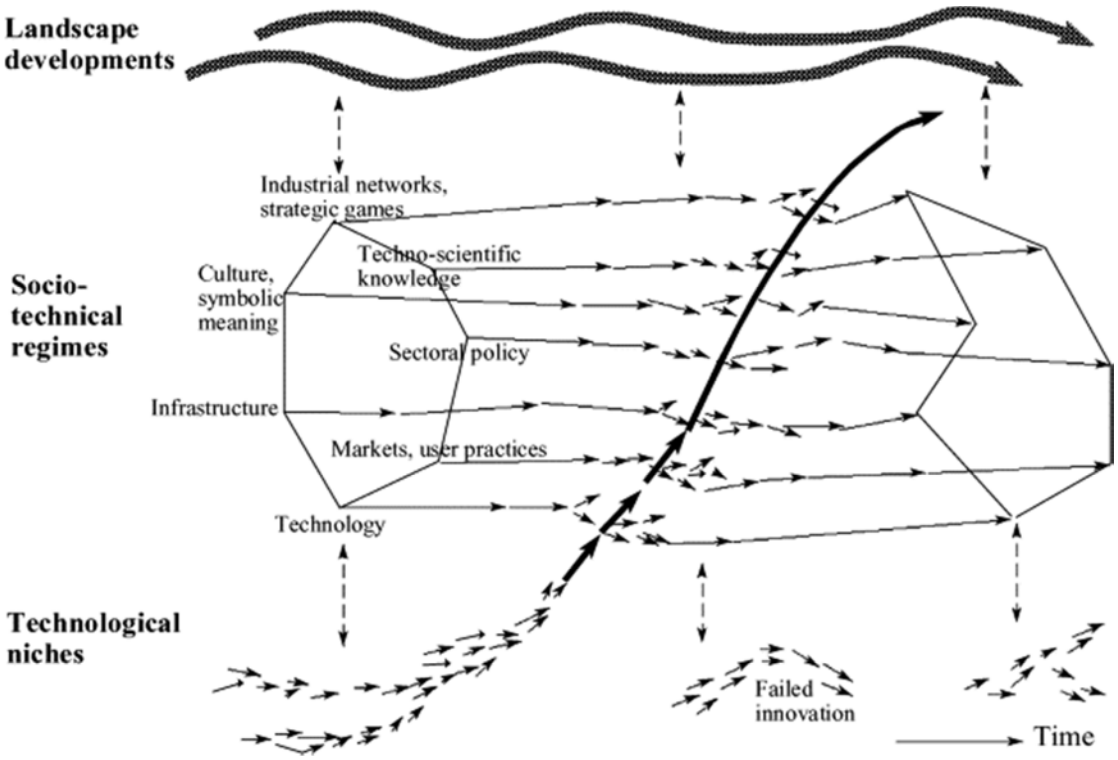

Figure 5: 'A dynamic multi-level perspective on technological transitions' from (Geels, 2002)

Although the multi-level perspective is described through hierarchical concepts (originally described as a "nested hierarchy" (p.1261, Geels, 2002) where niches were created within regimes), Geels later adjusted this in response to criticisms from Shove and Walker (2010) that niches are not necessarily realised in this spatial way. They were refined to be understood as "different degrees of structuration of local practices, which relate to differences in scale and the number of actors that reproduce regimes (and niches)" (p.38, Geels, 2011).

Criticisms and developments of the multi-level perspective

The multi-level perspective has been widely applied as a basis of analysis of the process and drivers of socio-technical system change (Markard et al., 2012). In empirical studies, the multi-level perspective is often applied to historical cases to enable consideration of a complete transition process (e.g. the transition from sail ship to steam ship (Geels, 2002), biogas development in Denmark (Geels and Raven, 2007), and periods of change in the gas industry in the UK (Arapostathis et al., 2013). Its allure has been attributed to its ability to consider multiple and complex drivers of transitions (Smith et al., 2005; Smith et al., 2010). However, despite its widespread application, it has been subject to a number of criticisms and has a number of areas in need of further development. This section discusses various aspects of these debates and also presents developments in the literature that have arisen in response. Of particular importance in this thesis, section 3.2.6 presents the influence of regime resistance in transitions and section 3.2.7 presents discussions on how to consider aspects of geography in transitions (section 3.2.7).

A number of criticisms of the multi-level perspective focus on how scholars have understood and applied the key concepts of niches, regime and landscape "levels" in empirical analysis. The subjective definition of the boundaries of the socio-technical regime within empirical studies leaves the process of analysis vulnerable to potentially missing important influencing dynamics by drawing artificial boundaries around a system (Markard et al., 2004; Smith et al., 2005). For example, it could be argued that the UK's system of heat supply has its own socio-technical regime within an empirical study. Alternatively it could be viewed as a sub-regime of a wider UK energy regime, or indeed as part of broader European or global energy regimes. Consideration and discussion of the implications of regime 'boundary' choices is therefore important when applying the multi-level perspective empirically.

A second criticism centres on the lack of detail provided by the multi-level perspective literature on how the regime and landscape levels interact with niches and each other to shape a transition pathway (Geels and Schot, 2007). Despite an original aim of the multi-level perspective being to give greater consideration to

the influence of regime and landscape dynamics within transitions, the framework has continued to receive criticisms for being a "bottom-up" process that is too focused on niche innovations (Berkhout et al., 2004). Smith et al. (2005) also highlighted a lack of attention to the detailed characteristics of regimes within empirical examples, resulting in a perception of the regime as a "monolithic" or "homogenous" entity and "neglecting important differences in contexts" (p.1492, Smith et al., 2005).

In an attempt to develop applications of the multi-level perspective approach in studies beyond this assumption of a 'bottom-up' process, Geels and Schot (2007) present a typology of transition pathways, to add clarity and detail to the influences of the meso- and macro- level dynamics:

- **Transformation transitions** take place purely due to influences from the landscape-level. Niche innovations are not sufficiently developed to be able to take advantage of the window of opportunity. As a result the regime dynamics are reconfigured through adaptation of internal regime processes.
- **De-alignment and re-alignment transitions** take place when there is no clear niche innovation that is sufficiently developed, but tensions within the regime are sufficiently strong to prevent re-alignment of the regime by existing regime actors. This leaves space for several under-developed innovations to compete and begin to diffuse, until a new regime stability is established, incorporating the winning innovations.
- **Technological substitution transitions** take place when a niche innovation is sufficiently developed to break through and replace the existing regime at the point where a window of opportunity is presented (generally as a result of landscape 'shock').
- **Reconfiguration transitions** take place when 'symbiotic' innovations are adopted on a small-scale within the incumbent regime to solve local problems. Over time, their presence triggers adjustments to the regime structure as a whole.

These are presented as distinct typologies, but in practice Geels and Schot (2007) recognise that pathways are unlikely to conform purely to one form. For example, they may take place over a sequence of different sub-transitions (Geels and Schot, 2007).

3.2.6. Regime resistance

A further development in research on the multi-level perspective has focused explicitly on considering politics and power in the incumbent regime and how this can lead to an active resistance to sustainable transitions (Turnheim and Geels, 2012; Geels, 2014). This avenue of research was in response to a third set of criticisms of the multi-level perspective that argues that the framework neglected to consider the politics and agency affecting actors working to reproduce an incumbent regime, or working to support shielding, nurturing and empowering processes for innovations (Smith et al., 2005; Smith and Raven, 2012; Shove and Walker, 2007). In particular, for analysis considering a normative approach to socio-technical transitions, they recognise that there has been too great an expectation that supporting sustainable innovation alone will be sufficient to bring about a sustainable transition, without giving sufficient consideration to the agency of niche actors and the resistance posed by the incumbent regime.

Späth and Rohracher (2012) argue that the multi-level perspective does not pay sufficient attention to the influence of regime-embedded actors in enabling a niche innovation to diffuse into the regime. Local niche actors can be supported but also hindered by the actions of regime actors who have influence and power within the regime. For example, Hodson and Marvin (2010) explore the role of cities in driving sustainable transitions using a case study of the Greater Manchester, UK. They argue that the formation of actors' visions and strategies at the city-level were influenced and restricted by national and regional interests towards favouring the prevailing regime, preventing consideration of more radical visions informed by local actors less invested in the incumbent regime.

To take greater consideration of politics and power within the multi-level perspective, Geels (2014) build on themes of regime 'lock-in' within the socio-technical transitions literature, and highlights four ways that incumbent regimes pose a resistance to transitions:

1) **Use of instrumental forms of power:** Regime actors can use their existing access to resources such as money, staffing capacities, or access to media or decision makers to further their own interests. Regime actors usually have access to greater resources to support regime reproduction and incremental adaptation than niche actors (Avelino and Rotmans, 2009).
2) **Use of discursive strategies:** Regime actors can use their existing powers and resources to frame what and how is being discussed; seeking to shape what people care about (and what they don't think is important), and what people see as the 'best' solution to a problem.
3) **Use of material strategies:** Regime actors can draw on their existing developed technical capabilities and financial resources to improve the technical sub-regime, making radical innovations seem less necessary.
4) **Use of broader institutional powers:** The regime can have embedded political cultures, ideology and governance structures that grant privilege to embedded regime actors e.g. a liberalised market ideology, where 'picking technology-winners' by government is discouraged, grants privilege to actors with established capabilities, market positions and resources.

(Geels, 2014)

The concept of 'destabilisation' of regimes has also begun to be explored (where reproduction of core elements of the regime are weakened). For example, Turnheim & Geels (2012) explore the process of destabilisation by drawing lessons from the history and destabilisation of the British coal industry. They highlight the commitment of industry actors to an 'industrial regime' defined by specific technological knowledge, core beliefs, mission and industry regulations. They argue that the fossil fuel industry actors "will not simply roll over and destabilise" (p.46, Turnheim and Geels, 2012). For their historical example, they found that the destabilisation process was multi-dimensional with a range of important influencing external and endogenous pressures, from policy approaches, public discourses, political strategies of incumbent actors, economic industrial problems within the incumbent regime, as well as a need for attractive and legitimate visions of alternative futures. They argue that "cultural criticisms and

political contestations of the incumbent regime are just as important as stimulating green innovations" (p.49, Turnheim and Geels, 2012).

This area of the literature is still under-developed empirically. Chapter 8 makes an empirical contribution to the understanding of regime resistance and destabilisation by exploring actor agency in the context of empowering processes for DH niches in the UK. Resistance from the incumbent regime is considered as a central part of the analysis.

3.2.7. Consideration of geographical scale and geographical unevenness in socio-technical transitions

Linked to these arguments for more elaboration on socio-technical transitions processes, there have also been calls to explore the role of geographical scale in transitions in more detail (Bridge et al., 2013; Coenen and Truffer, 2012; Coenen et al., 2012). These arguments recognise that the impacts of a socio-technical regime may vary across different geographical contexts (e.g. variation in forms of economic activity and structure within a system, impacts on urban vs. rural areas, etc.). A significant proportion of studies of socio-technical transitions to date have focused on national level systems (38%), whereas only a minority focus on other geographical scales such as urban (6.5%) or regional levels (6%) (or internationally) (Markard et al., 2012).

Initial studies on the role of geographical scale within the multi-level perspective framework have sought to move beyond treating the spatial context of transitions as a "passive background variable" (Coenen and Truffer, 2012). They highlight how a transition can vary across space, influenced by specific local contexts. Coenen et al. (2012) challenge the implicit assumption within the multi-level perspective framework that transition actors are able to interact, regardless of the geographical scale at which they operate. In reality "actors might substantially differ in their access to resources at different geographical levels" (Coenen et al., 2012). They point out that there is a link between the spatial embeddedness of institutions and the strategies that actors employ to deploy innovations and diffuse them. (Bridge et al., 2013) build on this idea, and highlight the impact of the spatial embeddedness of the incumbent regime in terms of the physical built environment and infrastructures of the incumbent regime that have sunk capital investment

costs, as well as the "place-based cultures of consumption that surround certain energy technologies" (p.338, Bridge et al., 2013). These spatial barriers cause additional resistance to a transition to wide scale uptake of a new innovation.

A further dimension of geographical scale to consider within the multi-level perspective framework is the "geographical unevenness of transitions" (Coenen et al., 2012). The differences in the physical, institutional, and political contexts of territories can lead to uneven development and diffusion of innovations, with some areas particularly suited to niche creation, while others being more resistant (Bridge et al., 2013; Coenen et al., 2012). For example, an off-gas area might present less resistance to innovations with alternative heat technologies than one where the innovation must compete with cheap gas boilers with existing gas supply infrastructure.

Späth and Rohracher (2012) use an empirical example of the remote alpine region of Murau in Austria, to demonstrate how a reconfiguration of actor networks can support the diffusion of sustainable energy. This demonstration at a regional level within an incumbent regime enables the alternative configuration to gain legitimacy for wider uptake.

> "Cities and regions are often large enough to incorporate at least some of the systemic properties of existing regime structures. […]. At the same time they can be small enough to exploit the advantages of proximity for the creation of new actor networks, discourse and institutions for alternative socio-technical configurations." (p.467, Späth and Rohracher, 2012)

These regional specific configurations can lead to uneven development, but also variations in transition pathways across space within a regime. For example, uneven development allows for the possibility for the co-existence of multiple niches and transition pathways in different spatial territories across a regime (Bridge et al., 2013). These alternative spaces can compete with or support one another. For example, Garud and Karnøe (2003) show how the formation of the wind industry in Denmark was supported by the development and eventual collapse of the wind industry in the US. Considering the reasons for spatial differentiation in transitions offers an opportunity to identify some of the changes

that might be needed from the incumbent regime to adopt a new innovation. Given the important spatial dimension of introducing decentralised DH into the case study's highly centralised energy system, issues of geographical scale and unevenness are considered at various points within the empirical chapters of the thesis and discussed again in the final discussion chapter (Chapter 9).

3.2.8. Co-evolutionary framework

The co-evolutionary framework combines socio-technical transitions theories with co-evolutionary approaches (Foxon, 2011). It seeks to provide a more explicit consideration of user practices and economic factors (two dimensions of sustainable transitions that are considered to have been under-represented within socio-technical approaches) (Shove and Walker, 2007; Foxon, 2011).

Co-evolutionary approaches were developed from theories of evolutionary economics, where Norgaard (1994) first pioneered the application of evolutionary theory outside of biology. The theory considers actors to have bounded rationality rather than assuming neo-classical rational actors (Dosi et al., 1988). **Bounded rationality** recognises that actors must make decisions with incomplete information in a complex world, and so heuristics are used to guide decisions to act, shaped by previous experiences and cultural norms surrounding the actor. Therefore, actions do not seek to maximise for the best possible outcome, but instead seek to reach a satisfactory outcome defined by the actor (Gigerenzer and Selten, 2002). The approaches use the biological evolution theories of **variation** within a population, **retention** of characteristics from one generation to the next, and **selection** according to the characteristics most suitable to the selection environment (Norgaard and Kallis, 2011). The concept of evolution is applied more broadly, not only to species populations but also to populations of organisations, technologies and ideas, (Kallis, 2007), that together form socio-technical-environmental systems. Two systems are said to co-evolve when they have a "causal influence on each others' evolution" (p.2262, Foxon, 2011).

The **co-evolutionary framework** identifies five critical co-evolving systems (Figure 6), in which each evolve under their own dynamics but also co-evolve with each other (Foxon, 2011). Guiding definitions for these five dimensions within the framework are detailed below, although Foxon qualifies that these definitions are

not prescriptive and should only be considered as a starting point for any analysis (Foxon, 2011).

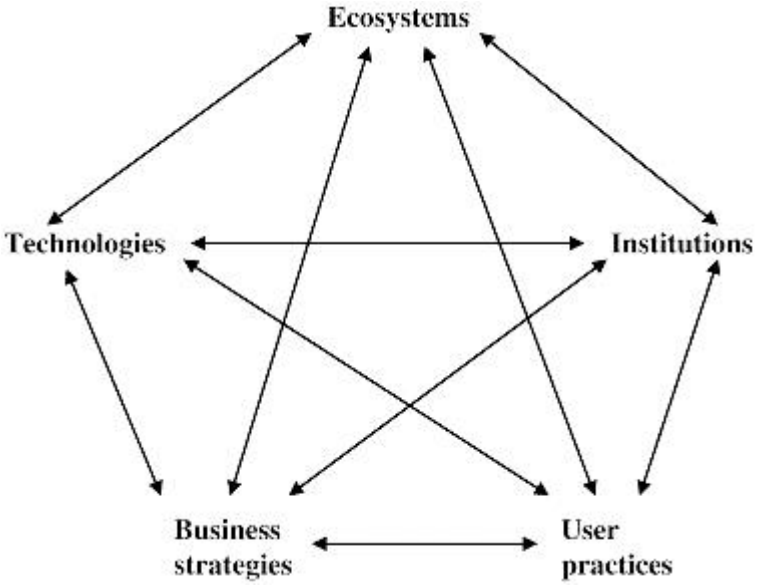

Figure 6: Co-evolutionary framework (Foxon, 2011)

Ecosystems are defined as the "natural flows and interactions that maintain and enhance living systems" (p.2262, Foxon, 2011). For example, this could refer to natural renewable resources such as wind or solar energy, or fossil fuels such as oil and coal.

Technological systems are defined as "systems of methods or designs for transforming matter, energy and information from one state to another in pursuit of a goal or goals" (p.2262, Foxon, 2011).

Institutions are "ways of structuring human interactions".

Business strategies are "the means and processes by which firms organise their activities so as to fulfil their socio-economic purposes".

User practices are "the routinised, culturally embedded patterns of behaviour relating to fulfilling human needs and wants" (p.2263, Foxon, 2011).

The framework differs from socio-technical transitions theories by viewing each dimension of the framework as a system in its own right, with its own evolutionary dynamics, but which co-evolves with the other systems. In contrast, the socio-technical approach emphasizes the interconnectedness of social and technical

factors specifically. By considering the causal interactions between each evolving dimension separately, Foxon (2011) argues that the co-evolutionary framework offers a more detailed understanding of why the overall system dynamics take particular trajectories, creating a level of analytical detail that would not necessarily come out through the multi-level perspective. He suggests it can be applied at the micro, meso or macro level studies. To date, the co-evolutionary framework approach has mainly been applied to meso and macro-level studies to inform policy and understand how systemic change can take place. For example, studies have considered long-term pathways to change, focusing on infrastructure change such as energy networks or storage (Roelich et al., 2015; Bolton and Foxon, 2013; Taylor et al., 2013) or scenario pathways to a low carbon electricity system (Foxon, 2013) and the introduction of non-technical innovations such as alternative energy service company business models (Hannon et al., 2013).

3.2.9. Technology Innovation Systems

The Technology Innovations Systems (TIS) approach seeks to assess the success of a specified system for development, diffusion and use of a particular technology, or set of technologies (Bergek et al., 2008). It was designed as a framework to guide policy-maker thinking about approaches to facilitating introduction and diffusion of sustainable technologies, rather than the more traditional research approach of making a specific policy recommendation (providing policy "insights" rather than "recipes") (Markard et al., 2015).

The technology innovation system is conceptualised as a socio-technical system made up of actors, networks and institutions that influence the innovation process for a chosen technology. It is used as an analytical concept rather than necessarily perceived as a system by the actors, networks and institutions of which it is composed. The TIS approach focuses on processes within the system, known as functions. This focus on functions aims to move analyses beyond focusing solely on structural aspects of a system, such as infrastructures, institutions, networks and actor capabilities, which may result in different outcomes across different systems (Bergek et al., 2008).

Bergek et al. (2008) formalised a scheme of analysis for TIS to enable better comparisons between studies, outlining a series of steps for analysts to use. Key

aspects of these steps include defining the boundaries of the TIS for analysis and characterising the system in terms of structural elements and functional elements of the system. They outline seven key functions for consideration within this process, drawing from key literature on technology innovation:

1) The **knowledge development and diffusion** function of the TIS considers how the system combines and shares knowledge to support development and diffusion of the technology.
2) The TIS **influence over the direction of search** considers how well the TIS is able to attract actors, firms and organisations to participate in the system and enable its development.
3) **Entrepreneurial experimentation** considers the capacity of the TIS to experiment in the face of uncertainty and risks.
4) Assessment of **market formation** within the TIS considers how developed a market is for the technology (nursing, bridging, or mature), and the range of factors, such as user demand profiles or institutional stimuli, that drive or hinder market formation.
5) **Legitimation** within the TIS considers social acceptance of a technology within a system and the factors that facilitate this.
6) **Resource mobilisation** considers the ability of the TIS to mobilise resources including financial resources, human capital, and complementary assets such as supporting infrastructures or services.
7) Finally, **development of positive externalities** considers how the functional dynamics of the system as a whole are mutually supportive and therefore increase the success of the system as a whole. For example, an increase in the number of actors participating within the system (function (2): successful influence over the direction of search) could add to the legitimacy of the system (function (5): legitimation), and stimulate greater awareness and demand for the technology (function (4): market formation).

(Bergek et al., 2008)

After the functions of the system have been characterised, these are used to assess the 'goodness' or 'badness' of the TIS function as a whole. Bergek et al. (2008) suggest that this assessment should consider comparisons with the performance of other TIS examples, as well as the phase of development of the system, i.e. the performance of a system in the early phase of formation should not be judged on the same conditions as one that is in a growth phase. Based upon this assessment, the analyst can identify inducement and blocking mechanisms within the system and specify key policy issues to focus policy-maker thinking.

To date, the TIS approach has largely been applied to emerging technologies such as renewable technologies (Jacobsson and Bergek, 2011). The prominence of studies at the early phase of TIS development has led to criticisms that the approach needs further empirically-based development to enable it to better explore more advanced and long-term transitions. It has also received criticism for being inward-orientated (Smith and Raven, 2012), and for not taking sufficient account of the context around the TIS or the resistance posed by the incumbent regime (Geels, 2011).

3.2.10. Transitions management

The transitions management literature argues that complex sustainability challenges require a different type of governance to enable necessary transitions to take place. Transitions management was proposed by a number of Dutch researchers as a normative approach to governance of transitions, building on socio-technical theories on co-evolution of regimes (Loorbach and Rotmans, 2006; Kemp et al., 2007). Application of transition management in practice has been important for iteratively developing the theory (Kern and Smith, 2008; Loorbach and Rotmans, 2010). Perhaps most notably, the approach has been applied by the Dutch Government, who introduced it as official government policy within the Fourth Dutch National Environmental Policy Plan (Kern and Smith, 2008).

Transitions management is described as "directed incrementalism" (p.87, Kemp et al., 2007) and aims to "utilise innovative bottom-up developments in a more strategic way by coordinating different levels of self-organisation through new types of interaction and cycles of learning and action for radical innovations

offering sustainability benefits" (p.80, Kemp et al., 2007). It is structured with a multi-scale operational model, outlined in figure 7.

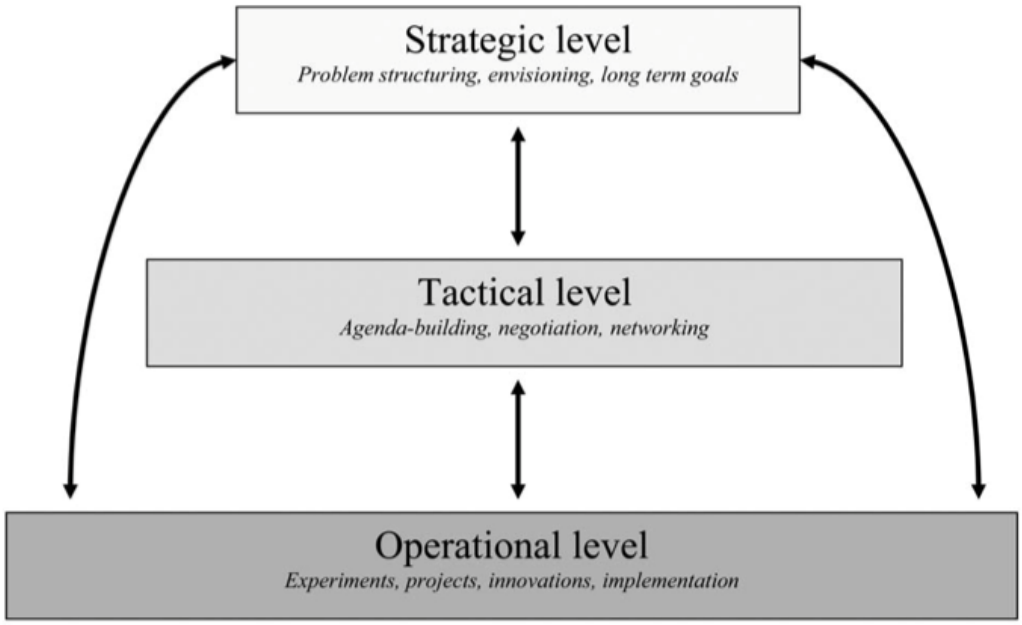

Figure 7: Multi-level approach to transition management (p.83, Kemp et al., 2007)

Creating shared visions for a transition is a crucial part of transitions management. To facilitate operation of the strategic level of the model, the concept of a transition arena was introduced with the aim of providing a separate space for discussions and consensus building, which could overcome challenges such as short political cycles and bypass existing policy processes that exist within the incumbent regime (Loorbach and Rotmans, 2010). A mix of public and private sector 'front runner' actors are selected to participate in the transitions arena to explore and frame a sustainability challenge and to develop long-term goals. The theory suggests that these front-runners should be selected carefully and be composed of a majority of niche-actors, as well as a number of supportive regime-actors (Loorbach and Rotmans, 2010). Based upon these long-term visions for transitions, a range of experimental short-term innovations and actions are defined. The process promotes diversity in these experiments, and emphasises learning processes for actors and networks, with reflection and evaluation incorporated as a key part of an iterative management approach (Loorbach and Rotmans, 2010; Kern and Smith, 2008).

Challenges and criticisms of transitions management

Although transitions management was adopted by the Dutch Government, it has attracted significant academic criticism as an approach. The notion of transition visions that are able to transcend incumbent regime resistance and individual actors' agendas is a particular challenge to the approach. Kern and Smith (2008) highlight the inherently political process of selecting actors to take part in the transition arena. They argue that the process for making this selection, as well as the composition of the resulting actor group shapes the visions and actions that are proposed. Berkhout (2006) also challenges the idea of the "meta-existence" of visions implied by the transitions management approach, to say that "it is likely that dominant and incumbent actors will be the most effective at defining and diffusing future visions" (p.300), and therefore alternative actors' visions may need active support to allow them to gain traction. This lack of consideration of politics and agency has also been a key criticism of the multi-level perspective conceptualisation of transitions (Smith et al., 2005; Shove and Walker, 2007; Smith and Raven, 2012).

Shove and Walker (2007) highlight the lack of consideration specifically of technology users and their habits and demand patterns in influencing transition dynamics. Applications of transitions management to date have all been to the early stages of facilitating a new transition (Loorbach and Rotmans, 2010) and this has not given relevant experiences for the development of appropriate conceptual tools "with which to enter these ordinary areas of everyday life" (p.768, Shove and Walker, 2007).

The delivery approach of transitions management has also come under criticism for lack of consideration of actor agency and regime resistance. Despite the theoretical creation of 'protected space' for transition experiments to develop, the established political networks and policy processes "do not easily give way to new routines" (p.4101, Kern and Smith, 2008). Transitions management advocates encouraging diversity of experiments and therefore the role of government should not pick specific 'winners' to support with policy measures. However, Kern & Smith (2008) argue that this can result in a lack of challenge to the incumbent regime and presents a major obstacle to enabling a successful transition. They

suggest that treatment of the incumbent regime requires more theoretical attention within transitions management. Both of these criticisms suggest that when considering approaches to governing transitions consideration must be given to the influence of the incumbent regime over different actors' agency, as well as the politics of who sets visions and designs governing measures to realise them.

3.3. Theoretical approach used in this thesis

The range of theories discussed in the preceding sections show the variety of potential theoretical lenses that could be applied to support analysis of the case study and address the research questions. It also highlights on-going debates in the literature that would benefit from consideration in the analysis within this thesis, particularly around actors' agency and the politics of governing of transitions.

The case study used in the thesis is an example of an energy system with little existing DH in the early stages of a potential transition. Where networks have been successfully developed this has been driven by local champions who have enabled supportive local circumstances for delivery of a project (Hawkey et al., 2013). The DH development process is therefore conceptualised as a number of local niche spaces and analysis draws on theories on the role of niches and the capacities of niche actors to govern transitions. In particular, the theories of strategic niche management (Kemp et al., 1998; Schot and Geels, 2008) and niche processes (Smith and Raven, 2012) are used to form the theoretical basis for structuring analysis.

As was noted earlier in the chapter, the defined scope of a socio-technical system within a study has implications for how the dynamics of a system are understood (for example, whether the regime boundaries defined by geography or sector) (Markard et al., 2004; Smith et al., 2005). Within this thesis, the socio-technical system is viewed as the energy system of Great Britain. Although many of the actors involved in the DH development process interact within international policy contexts and markets, the local nature of DH development makes the local, regional and national context particularly influential. These international

influences are therefore viewed as landscape pressures on the dynamics of Great Britain's socio-technical system.

As first discussed in Chapter 1, the focus of the overarching research question on 'governing' transitions seeks to draw lessons on the potential roles and capacities of actors across the public and private sectors to influence regime change through use of specific actions. In taking this normative approach, the analysis does not assume that it is possible for a single actor or a group of actors to control a transition. Instead, it looks to explore how different actors can drive and influence the direction of regime change by deploying specific governing measures. For example, Chapter 6 considers how local authority actors make use of heat mapping tools and Chapter 7 considers the role of intermediary activities at different geographical scales in supporting niche nurturing and empowering processes for DH.

As has been highlighted within this chapter, a key debate within the transitions literature is around the extent to which different niche and regime actors seeking to govern or influence a transition have the agency to choose their approach. For example, as was discussed in the previous section, transitions management has been criticised for a lack of consideration of the politics and power struggles involved in creating shared transition 'visions' (Berkhout, 2006). On a similar note, regime resistance can affect actors' agency to take actions which support more radical forms of change, for example preventing them from accessing resources to support such activities (Smith et al., 2005; Hodson and Marvin, 2010). These debates of actors' agency in governing transitions are particularly relevant for consideration within analysis to address the thesis research question, which seeks to draw lessons for governing a transition to DH. Therefore, these themes are discussed throughout the empirical chapters, and the influence of regime resistance forms the primary focus of Chapter 8, which considers the political narratives used by a range of actors across the case study with regards to a transition to DH.

Now that the thesis aims and research questions has been presented in the context of the existing theoretical and applied literature, the next chapter discusses the choice of methodology used to address the research questions.

4. Methodology

This chapter details the methodology applied to the development of the thesis. As has been introduced in chapter 1, the thesis research questions seek to explore specific aspects of a case study of district heating (DH) in Great Britain, to draw lessons for how to drive a transition to DH.

As first discussed in chapter 1, the challenges of governing a transition to DH in the context of Great Britain, where DH provides only a small proportion of heat supply, are concerned with the interaction of both social and technical factors. In order to consider both of these dimensions of governing a transition, analysis of the case study is informed and structured by a body of literature on governing socio-technical transitions.

DH is a technically mature technology that has been used and developed for decades in some countries. However, DH development in Great Britain is still at an early stage. The majority of activity is still focused on project planning and feasibility to create a viable business case for investment (CAG Consultants, 2015). Actors must create supportive local circumstances that enable a project investment decision to be made in the context of minimal national heat regulations and relatively inexperienced stakeholders. Where schemes have been delivered, their success has been attributed to the leadership of key local actors' social capital enabling the alignment of local circumstances for the benefit of the project (Hawkey et al., 2013; Webb, 2015). Aspects of the socio-technical literature on governing niche processes are therefore particularly relevant to this case study. As introduced in chapters 1 and 3, this literature considers processes that support actors to develop an innovation within a form of protected space that reduces the barriers imposed by the incumbent regime. Qualitative data is used to provide empirical evidence to explore the thesis sub-research questions; focusing on current gaps in the literature around niche empowering processes and actor agency in governing niche processes, seeking to add empirical evidence to inform development of this area of the literature.

This chapter is structured as follows: Section 4.1 outlines the reasons for the use of a case study approach and choice and scope of the case study. Section 4.2 covers the processes used for data collection including data collection methods and selection of interview participants. Section 4.3 outlines the method of analysis used to consider qualitative empirical data collected throughout the thesis. Section 4.4 discusses the strengths and weaknesses of the chosen methodology and its implications for the validity and reliability of the results. Finally, section 4.5 discusses ethical considerations within the thesis.

4.1. A case study approach

Within the thesis, a case study of DH in Great Britain is used to draw lessons on how a transition to district heating can be governed. Case study approaches can vary in their focus and application, but are broadly described as:

> "A strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence" (p.178, Robson, 2002) .

Yin (2014) suggests that case studies are best applied when seeking to understand "how or why some social phenomenon works" or where an in-depth description of a social phenomenon is required to answer the research questions (p.4, Yin, 2014).

The preceding chapters have highlighted the complexity of low carbon transitions and the need to introduce multiple, diverse technologies into a socio-technical regime that is not configured to support them. In order to be able to draw lessons for how to govern a low carbon transition, an in depth understanding of how different governing measures can shape social and technical change within different contexts is required. Each technology has different characteristics and requires different forms of actor practices and support for their diffusion. Differences in context can also influence the type of governance approach that is needed.

Given limited time and resources available for this thesis, restricting the scope of the study to look at the introduction of one particular technology, DH, enabled the

level of detailed analysis necessary for considering questions of governance of complex socio-technical systems. This would not have been possible in the time frame with inclusion of more technologies or a wider geographical scope. However, the relevance of the thesis findings for technologies and contexts beyond DH in Great Britain are considered and discussed in more detail in chapter 9.

4.1.1. Choice and scope of the case study

The single case study of Great Britain was selected for several reasons. First, Great Britain has a highly centralised energy system and a market-led approach to introducing new low carbon technologies following a history of energy nationalisation, followed by privatisation and liberalisation (Bolton and Foxon, 2013). This context of minimal government intervention enables better exploration of the socio-economic drivers and barriers to introducing new technologies.

The scope of the case study was restricted to Great Britain, i.e. England, Wales and Scotland, rather than considering the whole of the UK. Northern Ireland was excluded because responsibility for energy was wholly devolved to the Northern Irish Assembly and the context of its energy system is therefore separate and distinct from the rest of the UK.

The focus on DH also provides a particularly interesting technology focus for a case study. It is concerned with all three aspects of energy supply, distribution and demand. Its nature as a local infrastructure technology also means that issues such as high capital costs and investor risk perceptions, as well as lack of institutional support or strategic coordination are particularly strong. Finally, as a researcher based in England, selection of this case study made the practicalities of data collection easier to manage.

4.2. Data collection

A flexible research design was used for data collection to inform the case study (Robson, 2002), enabling the data collection process to be adapted and be re-focused as analysis of initial data increased the researcher's understanding of the case study's context and actors. DH development in the UK is in its early stages and

the energy policy context changed and developed several times during the period of this study. It was therefore important to be able to respond to these changes and explore their impacts on processes within the case study.

Given the importance of social aspects of change processes involved in governing a transition to DH, and in particular a need to consider subjective issues such as actor perceptions and agency, qualitative data was felt to be an important form of data to address the research questions. The focus of data collection was therefore on qualitative data sourced from key stakeholders and institutions involved in supporting DH development in Great Britain. Three types of data collection were used for this qualitative data: semi-structured interviews, a decision theatre research process, and primary literature.

Chapter 6 also uses quantitative data to complement qualitative analysis. The chapter, which explores the role of heat mapping as a governance measure for supporting niche processes, uses the outputs from a qualitative analysis to test the practical implications for design of a heat map to better support niche processes in the case study. The resulting heat map uses publically available quantitative data sets such as government published statistics. The data sets utilised are listed in Appendix E.

4.2.1. Semi-structured interviews

The main source of data used came from semi-structured qualitative interviews with key stakeholders involved in DH development. Semi-structured interviews were used over structured interviews since policy and practitioner approaches to DH delivery was in a period of fast development. In addition the under-researched nature of this area, particularly in countries with little existing DH such as Great Britain, made it hard to predict the focus or significance of an actors' involvement before an interview had taken place. This meant that it was important to have flexibility to follow up on particular areas of interest and shape the focus of an interview to the areas of activity of a given stakeholder.

Interviews were conducted face-to-face where possible. Where a face-to-face meeting was not possible interviews were conducted on the telephone. All interviews were audio recorded and transcribed for use in Nvivo software during

analysis (all transcriptions were done by the researcher except for 12 interviews originally conducted as part of an additional study, where funding had enabled this to be done by a paid transcriber. More details on this additional project are given in section 4.2.4). Interviews each lasted approximately an hour and were structured according to the research questions that were in focus during the phase of data collection.

4.2.2. A decision theatre

In addition to semi-structured interviews, a decision theatre research process was used to offer an alternative form of data collection. The method, first developed by Arizona State University, uses data visualisation, modelling and simulation to simulate a complex decision process with a group of stakeholders (White et al., 2010; Walsh et al., 2013; Bale et al., 2014). The method applied within this thesis is adapted from the original approach, which focused heavily on the use of detailed modelling and simulation to inform participant decisions. In order to enable understanding of the interactions between stakeholders throughout the stages of the district heating development process in the case study, scenarios were presented using maps, basic data and verbal descriptions of actors. This adapted approach aimed to stimulate discussions about actor interactions and attitudes as well as the technical data. The decision theatre research process is described in more detail in chapter 7.

4.2.3. Primary literature sources

Primary literature sources were also used as a form of data. These were compiled from formal policy documents published by the UK Government and the Scottish Government. The sources were used to explore the formal government policy positions, as well as to provide a form of data where formal interviews could not be obtained with relevant stakeholders (as was the case with the UK Government heat policy team). The primary literature sources used within analysis were:

- Association of Decentralised Energy. 2015. The Heat Trust. [Online]. [Accessed 01/11/2015]. Available from: http://www.heattrust.org
- CAG Consultants. 2015. Evaluation of the Heat Networks Delivery Unit. London, UK.

- DECC. 2012. The Future of Heating: A strategic framework for low carbon heat in the UK. London.
- DECC. 2013c. The Future of Heating: Meeting the Challenge. London, UK: Department of Energy and Climate Change.
- DECC. 2015. Delivering UK Energy Investment: Networks. London, UK.
- Scottish Government. 2015. The Heat Policy Statement: Towards Decarbonising Heat: Maximising the Opportunities for Scotland. Edinburgh, UK.
- Scottish Government. 2013. Heat mapping - a guide - For use by local government or other contracted organisations. Edinburgh, UK.
- Wiltshire, R., Williams, J. and Woods, P. 2014. A Technical Guide to District Heating. Watford, UK: BRE Trust.

4.2.4. Phases of data collection

Data collection was structured into three phases and analysis was conducted at each phase. This supported the flexible research design by adding an additional level of understanding of the case study context and the approach of key actors at each phase. Later phases built on this understanding to shape the research focus and selection of research participants.

Phase 1 involved 14 semi-structured interviews conducted with a range stakeholders involved in DH development between May 2013 and September 2014, combined with relevant primary literature from the UK and Scottish governments. This data forms the empirical basis for chapter 5, which is a pilot study to gain an in depth understanding of the case study as well as to identify promising areas for further and more focused investigation for addressing the research questions.

12 of these interviews were originally conducted as part of a project funded by the Chesshire-Lehmann Fund[5]. The funded project sought to explore the potential of spatial mapping to enable use of DH for alleviating fuel poverty (Bush et al., 2014). As part of the research process for this project, a set of 12 interviews were conducted with a range of local and regional level stakeholders involved in supporting development of DH projects. Interviews were split into two sections; section 1 focused on understanding the objectives, drivers and barriers of actors for deciding to try to develop a DH scheme, and section 2 explored how heat maps were used within the development process. Within the thesis, data from the two interview sections are used in separate chapters; section 1 of the interviews contributes data to chapter 5 and section 2 of the interviews contributes data to chapter 6.

Phase 2 involved the decision theatre (see section 4.2.2) in October 2014, where eight stakeholders representing a range of local actor types took part. This data is used to explore the role of intermediary activities in supporting DH development and niche processes. The decision theatre approach offered an ideal method to capture data relevant to intermediary activities about connections, relationships and interactions between different stakeholders. The analysed results from data gathered during this day-long process are presented in chapter 7.

Phase 3 involved collection of a further 29 semi-structured interviews conducted between March and August 2015, and inclusion of further primary literature sources published in the intervening period. This phase of data collection significantly expanded the number of stakeholder-types included in the study to add more assurance to the validity of the findings. Interviewees were selected based on information collected in the analysis of the previous 2 phases of data collection. They were made up of representatives from across

[5] The Chesshire-Lehmann Fund was set up to support research into issues surrounding fuel poverty (http://www.chesshire-lehmann.co.uk). It is administered by the charity National Energy Action. The project funding of £5,000 covered costs of travel for conducting interviews, interview transcription, the creation of a video to communicate the results of the research to relevant stakeholders, and contributed towards the costs of creating an online mapping tool. The outcomes of this work are presented as parts of chapter 5 and chapter 6.

the public and private sectors, and from across geographical scales (local, regional and national actors). Interview questions in this phase focused on actors' long-term approaches and attitudes to DH development, exploring how they had changed over time and their perceptions of risks and threats to a successful transition to DH in Great Britain. Analysis of data collected in phase 3 formed the empirical basis for chapter 8.

In addition, relevant data collected from local and regional public sector actors throughout the three phases, (representing 11 local authority actors and 3 regional level authorities), were combined to form the basis of analysis in chapter 6 focusing on the role of heat mapping in niche creation processes. The interview questions used for the semi-structured interviews are included in Appendix C, D and G.

4.2.5. Participant selection

Ensuring the interviewees were made up of a relevant and diverse selection of actors was key to building a valid and in-depth understanding of the case study. Based upon a review of the existing applied literature on DH in the UK and internationally, the interviewee selection process began by focusing on local authority actors as a key point of coordination or facilitation in many projects. Through the process of these early interviews with local authorities, further actor-types were identified as having a potential influence over the local DH development process. Over the first phase of data collection, and continuing throughout the second and third phases, an understanding of the range of actors involved in supporting or delivering DH was built up. This was used to select types of actors for interview. The range of actors interviewed in each of the phases is detailed in table 2. These were divided up into actors directly involved in facilitation or delivery of projects (local niche actors), and other actors involved in broader activities connected to DH such as policy makers, the regulator, consultants, trade associations and gas distribution companies (global niche actors).

Table 2: The range of actor-types interviewed in each of the data collection phases

		Phase of data collection		
	Actor type	**Phase 1**	**Phase 2**	**Phase 3**
Local niche actors	Local authority	5	5	7
	Housing association	1	-	-
	Public sector energy manager	-	1	-
	Community energy group	-	1	-
	Energy company	2	-	6
Global niche actors	Regional authority	2	1	3
	Consultant	-	-	3
	DH trade association	-	-	2
	Gas distribution company	1	-	3
	Number of distinct organisations represented	**11**	**8**	**24**
	Total interviews	**14**	**8**	**29**

Representatives of each actor-type were selected for interview based upon recommendations and observations of the DH sector over the three-year period of the research (2013 – 2015). They were selected as key leaders, decision makers or spokespersons for DH in their institution or industry. Numerous industry conferences, workshops, and government stakeholder consultation events were attended throughout this period of time, enabling the researcher to build up understanding and knowledge of the community of actors involved in DH development. In addition, a number of international DH-focused conferences and study visits were attended, enabling further contact with UK actors seeking to learn from international experience, but also enabling a greater understanding of how DH has been developed and embedded in other countries. A list of events that

were attended during the course of the thesis is included in Appendix A. The early stage of DH development in Great Britain meant that there were still a relatively small community of actors involved in project development. For example, there were only 115 local authorities funded in England and Wales under the Heat Network Delivery Unit (CAG consultants report) and in Scotland, 29 local authorities took part in the Heat Network Partnership Strategy Support Programme (Heat Network Partnership for Scotland, 2015). There were two trade associations representing institutions working on DH: The Association of Decentralised Energy currently has 22 members related specifically to DH development (although many more related to CHP and consultancy) (Association of Decentralised Energy, 2016), and the UK District Energy Association has 17 full members (and 99 associate members) representing all aspects of DH development (UKDEA, 2016). Therefore the activities described above were sufficient to enable effective identification of relevant stakeholders, and in particular meet and speak informally with many of them.

Given the early stage of DH development within the case study, the actors involved in DH development focused primarily on building niche actors' capacities to enable initial identification of opportunities and to deliver projects. The technology user perspective was often not yet the focus of their concerns. As a result, technology users mentioned within interviews was mainly limited to large heat consumers, particularly in the public sector, such as hospitals, universities and social housing. Although the perceptions and experiences of householders as potential technology users was recognised as crucial to the future success of the technology, the early stage of development of many projects meant that most actors were not yet engaging with the general public beyond social housing residents or through house sales in new housing developments. As a result of this focus, data collected in this study related to the technology user perspective is restricted to actors who have responsibility for large heat demands, who often also had an interest in owning or co-owning a network.

However, it would be anticipated that as a transition to DH developed, and the capacities of key actors within the case study became more established, then the

household-level technology user perspectives would become a greater consideration for niche actors seeking to support DH empowering processes.

4.2.6. Stratego project experience

The researcher's understanding of the case study and knowledge of relevant actors was also built up through a practical involvement in supporting DH delivery in Scotland. The researcher was employed part-time during the period of research to manage the Stratego project (Scottish Government, 2014) on behalf of the Scottish Government. The project, funded by Intelligent Energy Europe and the Scottish Government, aimed to help local and national authorities develop effective heating and cooling plans that are joined up, evidence-based and strategic. In Scotland, the project involved the seven local authorities that had cities within their area (Aberdeen, Dundee, Edinburgh, Glasgow, Highlands (Inverness), Perth, Stirling). The researcher was responsible for organising workshops that aimed to share knowledge from experienced energy planners and DH operators in Denmark with Scottish local authority officers and decision makers. The role was based within the Scottish Government Heat Policy Team for one day a week from July 2014, during a period of time where the Scottish Government Heat Policy Statement was being finalised (Scottish Government, 2015) and delivery was taking place of a programme for local authorities to support development of DH strategies.

These activities were not used directly as data within the research presented within this thesis. However, they informed participant selection, provided a means of testing and validating early thoughts within the process of analysis, and offered useful insights and understanding of the challenges for delivery and policy making for DH in Scotland. As well as adding benefits to the research process, the close interaction of the researcher with the case study had potential for introducing bias. Section 4.4 discusses in more detail the strengths and weaknesses of the methodology used within the thesis in terms of its validity and reliability.

4.3. Method of analysis for qualitative data: thematic analysis

The empirical qualitative data sets from the case study were analysed using thematic analysis (Braun and Clarke, 2006). This method is suitable for use with a

range of research approaches. For the purposes of this thesis it provided a flexible approach to data analysis that could be adapted and focused to answer the specific research questions of each of the results chapters (chapters 5, 6, 7, and 8).

Thematic analysis enables identification of patterns across a set of data, termed 'themes' (Braun and Clarke, 2006). A researcher can either take an inductive (bottom-up) approach or theoretical (top-down) approach to identifying themes. The inductive approach analyses the empirical data without initial consideration of existing theoretical literature, to enable the researcher to determine what themes are important independently of any existing literature. This approach is useful to give a picture of the overall data and particularly for under-researched areas. The theoretical approach uses the existing literature to focus the analysis by searching for particular themes already identified in the literature. This approach is useful for answering focused research questions that seek to build on existing literature or consider a particular detail of the data.

Another key analytical choice within thematic analysis is whether themes should be determined using a semantic level or latent level of analysis (Patton, 1990). A semantic level of analysis only describes explicitly observable aspects of the data content. The identified themes and research claims are then based on an interpretation of these descriptions. A latent level of analysis considers the underlying ideas and assumptions that shape the semantic content of the data. It therefore goes beyond describing patterns in the data to form the basis of theme identification.

Within this thesis, a theoretical approach to thematic analysis was used. Each chapter drew on relevant parts of the existing literature to shape an analytical framework. This framework was used as the basis for initial themes from which to code the data sets. Sub-themes were then identified within these. The frameworks used for each analysis, and their basis in the literature, are outlined within each chapter. A semantic level of analysis is used to describe the identified themes. This approach is taken due to the sole focus of the research on professional actors. The research interest focuses on the explicit statements and actions that actors are able

and willing to make in their work. A semantic level of analysis is therefore most appropriate for this work.

4.3.1. The 6 phases to thematic analysis

Braun & Clarke (2006) set out a process of 6-phases to conducting a rigorous and reliable thematic analysis. These phases are not meant to be linear and the researcher should iterate and repeat them until they are content that all relevant themes have been identified and that they accurately represent the data set. The phases are outlined below:

1. **Phase 1: Data familiarisation, including transcription of verbal data.** This phase enables the researcher to review each piece of data. Where verbal data has been collected this should ideally be transcribed. Where possible, transcription should be carried out by the researcher as part of the data familiarisation process (Lapadat and Lindsay, 1999).
2. **Phase 2: Generating initial codes.** In this phase the researcher identifies interesting aspects of the data that might form the basis of repeated patterns. Within this thesis, these codes were recorded using Nvivo coding software.
3. **Phase 3: Searching for themes.** Considering the initial codes made in phase 2, patterns are identified that connect codes together to form themes. Some coding may also be discounted at this stage. The themes identified at this stage may also be connected as sub-themes.
4. **Phase 4: Reviewing themes.** This phase considers the themes identified in phase 3 to (a) check that the data coded into each theme is coherent; and (b) that the themes represent the whole data set appropriately and whether there are any missing themes.
5. **Phase 5: Defining and naming the themes.** At this stage in the analysis process, the researcher seeks to articulate what is interesting about each of the resulting themes, checks that they do not overlap with each other, and begins to form an overall narrative for answering the research question.
6. **Phase 6: Produce the report.** The final phase of the analysis includes a write-up of the findings. The process of writing is considered an important part of the analysis process, and often leads to a return to previous phases

for further consideration. At this phase, the researcher should provide evidence of each of the identified themes, using extracts from the data. The report should go beyond data description and should form an argument in relation to the research question.

The six phases outlined by Braun & Clarke (2006) were applied within each of the analyses forming the basis of empirical chapters 5 – 8. The different theoretical approaches used to structure and focus the thematic analyses are outlined and justified within each chapter.

4.4. Validity and reliability of the study

Research outputs using qualitative and flexible research designs tend to be strongly influenced by specific and time-dependent contexts that make studies difficult to replicate. It is therefore important to consider strategies for managing the validity and reliability of this type of research (Robson, 2002) . Lincoln and Guba (1985) divide the possible threats to research validity into three categories:

1. **Reactivity**: where the presence of the researcher interferes with the setting or behaviour of people.
2. **Respondent bias**: where the respondent chooses to withhold information or answers questions in way that they perceive as wanted by the researcher.
3. **Researcher bias:** where the researcher's assumptions or preconceptions affect the research conclusions through processes such as choice of interviewees, or selection of data for analysis and reporting.

Given the regular contact and interaction of the researcher with many actors within the case study, researcher bias was a particular concern within this work. Potential for researcher bias was identified within participant selection, interview question design, and the analysis process. The researcher's work on the Stratego project was focused primarily on local authority actors in Scotland. This could lead to an unintentional emphasis on public sector perspectives within the research, whilst omitting the perspectives of the wider set of actors involved in DH delivery. The flexible research design also had the potential to exacerbate this problem

since the range of participants invited to interview was not pre-defined before the study began. Identification of and reflection on potential forms of researcher bias was used to reduce the impact of this (Ahern, 1999). By recognising areas of potential bias, the researcher could reflect upon the research process as it progressed and address issues where they arose. For example, research participants were selected from across the public and private sectors, and across different geographical regions to ensure that a broad selection of data was obtained, that did not focus too heavily on local authorities. In phase 3 of data collection, a conscious effort was made to interview balance the number of local authority actors with private sector energy company actors involved in DH development.

Conversely, the regular interaction of the researcher with stakeholders had a positive affect over the risks of reactivity and respondent bias. The researcher's involvement in managing the Stratego project and regular attendance at industry events meant that actors got to know and trust the researcher. The researcher was then able to select appropriate research participants (with relevant roles for the research); interview requests were more likely to be granted; and interviewees were more likely to give honest answers to interview questions. This regular contact also made informal validation of analysis results possible throughout the research process.

4.5. Ethical considerations

An ethical review process was undertaken before each phase of data collection was undertaken to assess the potential for risks or concerns of the research participants about the work (University of Leeds ethical review references: LTSEE-015; LTSEE-026; LTSEE-028). Consent was requested from all research participants to take part in the interviews or the decision theatre and to record interactions. A clear statement about the purpose of the research and how data from their interview would be used were also provided at this stage. Where data collection was done in person, permission was sought through a written consent form. Where this was not possible, verbal consent was received (e.g. when the

interview was conducted via telephone). Appendix B shows the consent forms used with researchers at each stage of the data collection process.

Interviewees and their organisations were anonymised within reporting of the analysis, using coding to indicate the types of organisations quoted directly. The names of the specific organisations represented by the research participants are also not listed due to the small number of people working on projects in most organisations, preventing the possibility of other stakeholders working out who was responsible for particular quotes. Anonymisation was important for minimising respondent bias, particularly when interview questions focused on issues such as stakeholder relationships (both internally and externally to participants' institutions). It was also important for private sector organisations that might deem information about their long-term strategic approach to DH development to be commercially sensitive. Final drafts of each chapter were also checked with interviewees to reassure them that anonymisation had been conducted appropriately (where a report or journal article was published in advance of the thesis submission, this version was checked with relevant interviewees).

4.6. Summary

A single case study approach is used within this thesis, using empirical evidence to make an applied contribution to actors seeking to govern a transition to DH within a low carbon energy system. A flexible approach to data collection, using semi-structure interviews, a decision theatre research process, and primary literature sources, has enabled adaption to changing contexts and actor priorities, offering a richer case study description as understanding of its complexities was developed. Details of the specific data and frameworks of analysis used are given within each results chapter. Informal interactions with stakeholders during events and Stratego project work formed an important part of validating the research outputs. Given the closeness of the research to the case study actors and context, careful attention was given to identifying and mitigating the risk of researcher bias.

5. Local authority visions and development approaches for district heating in Great Britain

5.1. Introduction

This chapter presents an initial pilot study of DH in Great Britain, exploring local authority actors' visions for DH and comparing these to the development approaches used by local actors to deliver new DH networks[6]. This is used as a basis to gain a more detailed understanding of the complexities of the case study, given the fast moving context of the case study and the relatively few existing studies focusing on DH in Great Britain (discussed previously in chapter 2).

Actors' visions or expectations for a technological innovation and future transition have an important role in shaping the direction that a transition might take (Hodson and Marvin, 2010; Schot and Geels, 2008; Hamann and April, 2013; Kemp and Loorbach, 2006; Borup et al., 2006). An actor's vision for a technological innovation is defined as a normative expression of the future situation and capability of an innovation (Borup et al., 2006). Berkhout (2006) breaks this definition down further to say that a vision has three characteristic features: it sets out objectives for what will be achieved if a vision were realised; how these objectives will be achieved in terms of social and institutional arrangements; and the technological requirements of the vision. In general, visions are recognised as providing a frame that can shape actor alliances and mediate across boundaries of scale or diverse communities, focus resources in particular directions, direct actor learning processes, and legitimate certain courses of action such as shielding policies to create a protective niche space (Schot and Geels, 2008).

[6] The work in this chapter also forms the basis of a journal article (copy included with thesis submission): Ruth E Bush, Catherine S E Bale, Peter G Taylor (in review), *Realising local government visions for developing district heating: experiences from a learning country*, Energy Policy

As was first outlined in chapter 3, in the transitions management approach applied by the Dutch Government in recent years, actors must mutually agree a transition vision which is then used as a basis to agree short-term actions within the framework of a long-term goal (Kemp and Loorbach, 2006). The approach seeks to use the process of vision creation to separate decision making from the confines of the incumbent regime. An alternative interpretation of the role of visions set out by Berkhout (2006) sees them as "resources that are deployed by agents in pursuit of private or sectional interests" (p. 300). Berkhout (2006) describes the range of visions held by different actors surrounding an innovation as competing "propositions" for how the future could unfold. These propositions are explored and tested until a particular vision comes to dominate over the others.

Actors' visions are constantly adjusted and influenced as their experiences and knowledge grow or change over time (Borup et al., 2006; Berkhout, 2006). The process of actualising a vision also leads to adjustment of visions as actors respond to the material realities of their context. In particular, the power and agency of different actors or interest groups influence which visions of the future become established. For example, Eames et al. (2006) use a case study of visions for a hydrogen economy in London to explore how visions move from being flexible narratives adapted by actors to suit their audience or objectives, to being grounded in the reality of a particular context. They observe that "actors and groups in positions of power will have greater ability to define what it means in their context" (p.372, Eames et al., 2006). Hodson & Marvin (2010) also explore this process of negotiation or struggle between actors to establish a dominant vision for a transition, highlighting the influence of different actor's agency to choose and realise more radical visions. Actors are not necessarily free or able to articulate or support radical visions for transition.

This chapter explores the visions articulated by actors actively working to develop DH in the case study. The study focuses primarily on the visions of local authority actors in the case study, who are highlighted by the UK Government and Scottish Government as crucial actors for enabling strategic development of large-scale networks (Scottish Government, 2015; DECC, 2013c). As was discussed previously in section 2.2.3, local authorities have often played this crucial role in countries

where DH is already successfully integrated into the energy system (Ericsson, 2009; Chittum and Østergaard, 2014). However, coordinating strategic DH development is a new role for local authorities in Great Britain, who must either shoulder the risk of development themselves, or create a local policy framework and institutional infrastructure to facilitate others to make investments. In the context of a highly centralised energy system, the entrance of new local actors brings with it a new set of drivers and perspectives that do not necessarily align with the existing energy regime. Exploring the drivers and visions of these actors taking on this new role, as well as their capacities to realise these visions, provides a good starting point for exploring the case study in greater detail.

The chapter therefore offers analysis on the following four research questions (first outlined in chapter 1):

1) What are local authority actors' visions for a DH transition?
2) What decision criteria and approaches are used to develop DH?
3) Do these approaches support realisation of local authority visions for DH?
4) What role do non-local authority actors play in supporting DH development?

The chapter begins by exploring local authority actors' visions for DH by considering their stated motivations and drivers for seeking to develop DH (section 5.3.1). These visions are then compared to the types of approaches that the actors are using to develop DH projects (section 5.3.3). This comparison offers an insight into the level of cohesion of visions across different local authorities. It also highlights issues of actor agency to choose and deliver their local vision for DH. Finally, the analysis is then expanded to explore the role of non-local authority actors and how they interact with local authorities within the DH development process (section 5.4). Section 5.5 discusses emerging lessons and themes from the pilot study. Based upon the analysis, key areas are identified that would benefit from further study to answer the thesis overarching research question: "What lessons for governing a transition to DH can be offered by the experience in Great Britain?" Section 5.6 offers concluding remarks on the contribution of the chapter.

5.2. Method

5.2.1. Empirical data

Data from phase 1 of the data collection was used as the basis of a pilot study. It was felt necessary to take this pilot study approach since at the time of the research process design there were still relatively few studies focusing on DH in Great Britain to support identification of areas of priority focus for answering the thesis research questions. This approach also ensures that an applied contribution to actors in the UK can be made with the thesis findings by focusing on relevant and current areas of opportunity for governing a transition to DH.

As described in section 4.2.4, a series of 14 semi-structured, in-depth interviews were conducted with key stakeholders involved in DH development in the north of England and Scotland including local authorities, central government and industry, between May 2013 and September 2014. Local authorities formed the main focus of the pilot study, as the key actors enabling local coordination and facilitation of development of new DH projects. The largest proportion of the interviews (7 out of 14) was therefore conducted with 5 distinct local authorities to reflect their critical role in facilitating and enabling DH projects [LA1, LA2, LA3, LA4, LA5]. Local authority interviewees were selected to explore a range of local contexts for DH development. All were based in the North of England and Scotland (1 Scottish local authority and 4 English local authorities). The local authorities had a mix of local economic characteristics that may be influential over the approach to DH development. For example, some authority areas contained heavy industry, others did not; some areas contained high levels of deprivation and fuel poverty, others did not. Two of the local authorities had existing, small-scale DH schemes. In both of these authorities, the schemes focused around social housing blocks of flats, and connected up neighbouring public and community buildings. The other three authorities were actively involved in DH development at the project planning stages but did not yet have existing schemes. The local authorities represented by the interviewees covered the following settlement types:

- 1 large city (population over 500,000 people)
- 2 medium-sized cities (population over 250,000 people)
- 1 small city (population of approx. 150,000 people)

- 1 small town (population of approx. 50,000 people)

In addition to local authority actors, 2 regional authorities were interviewed [RA1, RA2]. Regional authorities are formed of a collaboration of multiple local authorities and served differing purposes depending on the authority (e.g. one regional authority was focused on facilitating economic growth in a geographical region working on behalf of 10 local authorities). In-depth interviews with these actors offered access to further local authority perspectives, which acted as a check of the reliability and relevance of the data collected within the 5 local authority interviews used in this analysis. As well as providing a form of verification to the analysis of local authority data, the role of regional authorities and their relationship to local authorities is discussed separately in section 5.4.

Data from other key actors involved in DH development either as developers, operators or key anchor loads were also interviewed. These actors were selected based upon recommendations of interviewees and other experts working on issues connected with DH, as well as through the literature and attendance at industry conferences. Table 3 provides a summary of the actor-types interviewed within this pilot study (phase 1 of data collection).

Table 3: Summary of actor-types interviewed in phase 1 of data collection

Actor type	**Phase 1**
Local authority	5 (7 interviews conducted)
Housing association	1
Energy company	2
Regional authority	2 (3 interviews conducted)
Gas distribution company	1
Number of distinct organisations represented	**11**
Total interviews	**14**

This number of interviews does not provide sufficient data to form a representative picture of the visions held by local authorities working on DH in Great Britain. However, the interviews provided a means to explore the details and complexities of DH development with each of the interviewees to an extent that would not have been possible with a larger number of interviewees at this pilot stage. Since this work was a pilot study to support identification of areas for further study in later parts of the thesis, this level of detail was important to obtain.

Interviews were structured around identifying actors' long-term visions for DH and their decision criteria within their development approach. They were recorded and transcribed for analysis, with the exception of two government meetings where a formal interview did not take place. Additional information was gathered from policy documents and government reports to support analysis of

the interviews. Appendix C provides an example of the questions used as a basis for discussion within the interviews.

Use of data collected through the Chesshire-Lehmann funded project

As was highlighted in Chapter 4, 11 of these 14 interviews were originally conducted as part of a project funded by the Chesshire-Lehmann Fund. The researcher provided ideas and input from inception of the project, which explored the potential of spatial mapping to enable use of DH for alleviating fuel poverty (Bush et al., 2014). The motivations and drivers of niche actors were explored as part of the project, to give an understanding of why actors would be likely to use a spatial mapping tool for DH development. Similarly, decision criteria used by actors within project development were explored to inform the design and development of a relevant spatial mapping tool. Interview questions were kept general and did not focus on fuel poverty explicitly. This enabled the same questions to be used in later interviews conducted for this chapter.

5.2.2. Analytical approach

As described in detail in chapter 4, a thematic analysis method was used to identify interesting aspects of the data relevant to the research questions (Braun and Clarke, 2006). The analysis was initially coded into categories of relevance to the chapter's research questions (shown in table 4), using Nvivo software. Relevant and interesting themes were then identified within the coding. These themes are presented in the next section.

Table 4: Initial coding categories for the thematic analysis of the qualitative interview data.

Research questions	Coding categories
Local authority visions for working on DH development	- Drivers and objectives
Decision criteria used within local authority actors' DH development approaches	- Social, Environmental, Economic - Access to resources - Actor roles - Actor capacities
Supporting factors / barriers to DH development approaches supporting realisation of local authority actors' visions	- Resources - Capacities - Context
Role of non-local authority actors in DH development	- Public sector - Private sector

5.3. Results

In this section the research questions are addressed in turn, using evidence from the thematic analysis.

5.3.1. Local authorities' visions for DH development

Analysis of data from the five distinct local authorities considered the drivers and objectives articulated within actors' visions for DH (a characteristic feature of a vision as set out by Berkhout (2006)). Visions varied across the different actors, but all sought to achieve multiple forms of social, environmental and economic value through DH development. The following quotes provide illustrative examples of the range of drivers that were articulated by the local authority interviewees:

- Economic visions focused on increasing the competitiveness of the local region, using DH to attract industrial activity to the area and thus creating more local jobs.

"It's economically focused. Creating more development, you know, building more homes creating more jobs." [LA4]

- Alleviation of fuel poverty and improvement in housing quality (particularly local authority-owned housing stock) featured.

"*We want to have tenants living in good quality accommodation and they can afford to live there and it's affordable to pay their fuel bills."* [LA2]

In Scotland, the link to fuel poverty alleviation was also actively supported by the Scottish Government. For example, during the period of data collection for this pilot study, the Scottish Government released a press release announcing the development of DH networks emphasizing their benefits for reducing fuel poverty (Scottish Government, 2015; CHPA, 2014).

- City carbon reduction targets were also linked to the focus on DH, as a technology that could be deployed at the local level.

"*We are going to establish ourselves as an energy city and to achieve our carbon reduction targets we are going to do this through our district heating network."* [LA1]

However, for some actors, carbon reduction was held alongside other priorities rather than at the forefront of the narratives around DH.

"The environmental side, the carbon reduction side, does come into it. But that's extra." [LA4]

"I think carbon would come as an underpinning to all of it." [LA2]

Carbon reduction also had a financial aspect, as public sector organisations that were not covered by the EU emissions trading scheme, such as most local authorities, were required to buy allowances for the tonnes of carbon

> they emitted under the Carbon Reduction Commitment (CRC)[7] energy efficiency scheme. Therefore, the ability to deliver carbon savings through the use of DH could offer financial savings to public bodies.

Visions often emphasized multiple types of value from DH at once. For example, several actors cited a driver as the need to reduce heating costs for both domestic and non-domestic customers. For domestic customers this had the potential to offer social benefits of reducing fuel poverty, increase health and wellbeing, and make the area attractive to live in. For non-domestic customers this could offer economic benefits by reducing energy costs for organisations and businesses, supporting potential economic growth or financial sustainability of businesses in the area.

Visions were often tailored to the specific political priorities of their local government. For example, DH was connected with other important parts of local authority activity. In one case, DH was linked to a local authority's wider responsibilities to regenerate council-owned housing stock. DH was seen as a solution for improving the living conditions of residents in social housing as well as meeting regulatory requirements for social housing standards. This linking of multiple priorities was common for actors seeking to demonstrate the need for new DH schemes in the context of limited resources and existing responsibilities for the local authority.

> *"Probably first pass we are looking at other investment priorities. So there are certain areas that the council wants to regenerate." [LA2]*

In general, the interviewees' visions articulated social, environmental and broader economic societal value above achieving financial profits from a scheme. Local authorities were aiming to develop DH networks as a means of delivering complex value to their area. This differs from what would be expected from traditional UK energy system actors within the private sector, who would require commercial rates of return for their activities.

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[7] The carbon reduction commitment applied to organisations that have a half-hourly metered electricity consumption greater than 6 GWh per year, and therefore includes local authorities that incur additional costs for electricity use.

5.3.2. Development approaches used by local authorities to deliver their visions for DH

This section now explores the activities that local authority actors were using to realise their visions for a DH transition. The decision criteria that actors used to choose their approach to developing a project were coded within the analysis. Three distinct 'development approaches' were identified within the process of thematic analysis: the funding-driven, commercial, and strategic approaches. The following sections consider these in turn and discuss whether they support the long-term realisation of local authority actors' long-term visions.

The public funding-driven approach

Under the public funding-driven approach, local authorities focused on accessing sources of public funding to cover all or part of the capital costs of a project and enable a viable financial business model. This reduced the level of investment risk for the scheme developers and offered the potential to keep consumer prices low by removing the need for recouping capital investments with heat sales. Funding came, or was being sought, from European sources (e.g. the European Regional Development Fund (ERDF)) or the Energy Company Obligation (ECO).

Often the criteria of these funding schemes aligned with the objectives of local authorities, particularly those that were aimed at improving housing standards and reducing fuel poverty. For example, ECO funding was used to deliver energy efficiency and DH schemes to improve housing quality. This enabled local authorities and housing associations to meet their direct responsibilities in terms of social housing quality standards as well as reduce fuel poverty and carbon emissions. DH schemes, installed alongside other energy efficiency measures, offered an opportunity to supplement existing budgets to achieve a higher standard of housing for social housing residents, and had the potential to interconnect into larger DH schemes at a later date. Even where social housing had been passed onto an independent housing association, the local authority often played an important role in facilitating access to funding to enable a project to go ahead. (The independent housing association actor interviewed in this phase of data collection was interested in the potential of DH in support of providing affordable warmth for their residents, but the association's housing stock was

geographically disparate and it was unable to take the lead on a scheme without local authority coordination across the area more broadly.)

The funding-driven approach posed challenges for realising broader long-term visions for DH. Problems of resource, a lack of local authority willingness to take on financial risk, and a lack of interested private investors led to a feeling of reliance on funding to enable any form of action. One interviewee stated:

> *"There is no way we could deliver this without ECO funding."* [LA1]

The need for external funding in this development approach meant that planned projects remained at the mercy of political changes in policy. During the 12-month span of this first phase of data collection, there was a significant reduction in the scale of ECO funding (OFGEM., 2014).

In addition, projects must also conform to the criteria of whichever funding scheme is being accessed. Project viability is, therefore, ultimately determined by the funding criteria rather than by the strategic objectives of a city or region-wide energy plan.

> *"I think the projects have probably just evolved as and when funding has become available."* [LA5]

There was evidence of social housing managers and energy companies working together to develop schemes, enabling them to meet their respective responsibilities in terms of housing quality standards and the obligations under ECO. However, these actions were not linked to long-term visions for DH and instead led to stand-alone, small-scale projects. This approach had been used to get small stand-alone projects off the ground, and offered an opportunity to support many of the social visions held by local actors in the short-term. However, its vulnerability to policy changes had potential to hinder projects with development times of many years and made it difficult to form a basis for long-term strategic planning for DH.

Commercial approach

A second DH development approach involved demonstrating the potential for commercially viable projects through use of heat mapping and stakeholder

engagement. Consultants were used to conduct energy masterplanning and financial viability studies to identify opportunities in an area. Viable business cases were determined by their ability to deliver a commercial level of financial profit on investment. Evidence of this opportunity could then be used to attract private sector investment from district heating energy companies to deliver projects in their area without requiring the local authority to take on the risks and financial burdens of development themselves. Within this study a regional authority took this approach on behalf of a number of local authorities in their region, rather than an individual local authority.

> *"We would identify the opportunity and then we could go out to the market and say "look, we think we've got an opportunity in [X] town centre, for instance. Are you interested in working with us to develop the opportunity?"* [RA1]

The Heat Network Delivery Unit (HNDU) seemed to primarily support this commercial development approach. Over £9 million of funding had been awarded to 90 local authorities across England and Wales since January 2014 to enable them to conduct feasibility studies and develop business plans "which can be used to attract commercial investment" for DH projects (UK Government, 2014) . As a result, there had been an increase in the commissioning of consultants to carry out heat-demand mapping studies to identify the most commercially viable sites[8]. For the actors interviewed here, heat maps focused predominantly on techno-economic criteria, with the aim of identifying potential for commercially viable schemes where private financial investment could be attracted. There was little inclusion of social or environmental criteria in these examples. This is clearly at odds with many of the local authorities' articulated visions for DH. However, the functionality of heat maps is dependent on the data that is included and the questions that actors apply them to. There is therefore potential for the utilisation of heat maps to be adapted to a range of priorities.

[8] 70 out of 115 successful local authorities were funded to commission heat mapping activities (accounting for 9% of allocated HNDU funding) between 2013 and 2015 (CAG consultants, 2015)

Strategic approach

The final approach described within the local authority interviews was the strategic approach. Many local authority visions focused on these larger scale schemes that were able to realise the broader set of benefits for their area, rather than focusing solely on project-based rates of financial returns. This approach used strategic energy planning to coordinate a phased rollout of DH, with expansion and interconnection of networks over time. Interviewees cited visions of projects that linked mixed demand portfolios with multiple low carbon heat sources, for example linking dense housing, commercial sites such as shopping and leisure centres with potential heat sources from industrial and waste heat sources, as well as thermal storage for balancing of intermittent heat sources. As previously highlighted, this type of DH network that extends across a large area, drawing on multiple heat sources, is likely to bring greater economic and environmental benefits to the energy system as a whole (Woods et al., 2005). The strategic approach is also supported by lessons from Denmark which highlight the benefits of a locally-coordinated development approach based upon a plan using socio-economic criteria for determining the optimum level of DH provision for a given area (Chittum and Østergaard, 2014).

Actors recognised that this approach required some form of 'cross-subsidy' between the most commercially viable sites with high heat-demand densities (e.g. new-build commercial developments) and other sites (e.g. retrofitting into domestic housing) that offer wider social and environmental benefits. One practical way actors saw to achieve this type of development was by retaining a form of local authority ownership in new schemes, and then re-investing the profits from initial schemes into those that were perceived as higher risk to private investors. They also sought to use large public sector heat loads such as museums, civic buildings, schools and leisure centres (often already under local authority management) as anchor loads to enable the viability of retrofit schemes or to expand existing networks.

> *"The council is currently very keen to invest in something like this to obviously generate revenue so we can maintain our level of governance around how it is*

> *developed in the future. We don't want to just give it away to a developer who just wants to cherry-pick."* [LA3]

> "[*We are] very keen to have a stake in whatever we build so we're looking to invest in it*" [LA2]

This strategic development approach was clearly an ambition for some of the local authorities interviewed in the study. However, within this analysis there was no evidence that this strategic approach had progressed from ambition through to delivery for any of the actors.

> *"We have certain key areas in [the city] that we want to look at for putting a district heating network across [the city], you know, almost like a web approach with the areas that we look to target, but we're really only at a discussion stage."* [LA3]

The role of the local authority within project development was a key challenge for many actors. Although retaining at least some ownership in schemes offered the local authority an influence over the direction of future plans for expansion, it also required significant commitment of resource and shouldering of risk.

> *"So I suppose we are in two minds about that because on the one hand it is very tempting to get someone to come in and just make the investment and own and operate and we will just take the energy, presumably at reduced costs for the agreed time. But we can access finance much cheaper than a lot of other companies who would probably want to buy into it in another way. So it's likely to be a partnership instead of someone just coming in to invest and say yes, that's how we sell energy. But yes, there are lots of different ways of doing it and we haven't got a preferred one at the moment."* [LA2]

5.3.3. Barriers to local authorities taking a strategic development approach

The interview analysis highlighted a number of barriers that prevented local authority actors from adopting the more strategic mixed development approach. The emerging themes supported many of the findings of a study undertaken for the UK Government focusing on barriers to development of DH in the UK (BRE et al., 2013).

A lack of staff resource came out consistently throughout the interviews. Budget cuts and regular restructuring, as a result of austerity measures, meant that there was often a lack of internal capacity to deliver essential activities such as stakeholder engagement. In addition, although the local authority interviewees were committed to developing DH, their work was not always supported or understood by their senior managers or by other departments. For one local authority, where senior-level support was present, the impact of austerity budget cuts was felt to be a threat to a long-term commitment to activities on DH.

> *"The city council is undergoing major changes in terms of budget cuts and senior management. They're restructuring. …We may have to start… well, almost start over again, convincing the new senior management team that this is the right thing to do."* [LA3]

All of the local authorities interviewed were new to the process of DH development and they sought advice and guidance where available. The support and funding offered by the UK Government's Heat Network Delivery Unit (HNDU) was clearly valued by local authority officers. In particular, it offered them connections to other local authorities with similar challenges to themselves, enabling peer-learning through sharing of experiences on key issues such as financing of schemes, business models and planning policy. However, despite the recognition of the positive impact of HNDU by the interviewees, they did not see the support provided from HNDU as supporting a full strategic approach. For example, realising social benefits with DH was not recognised explicitly in the HNDU funding application criteria, and instead commercial profitability was emphasised (DECC, 2014). The effect of this was evident, for example, in one of the experiences of the interviewed local authority actors, where fuel poverty was cited as an explicit objective of their work on DH, but was omitted as a factor for consideration in their heat mapping and energy master-planning specification to consultants. This type of narrow focus on commercial viability of projects had potential to hinder strategic approaches over the long term.

The issue of lack of internal staff resource was also not addressed by the HNDU support package. Local coordination and facilitation were important for

developing an understanding and appreciation of the potential of DH amongst local stakeholders. HNDU's policy of encouraging widespread commissioning of reports from consultants was succeeding in bringing in expertise on DH, but was not building the capacities within local authorities for long-term activities[9].

> *"I do understand for the really early stages and the very specific bits of work that you want to work with consultants who know how heat networks operate but we just want to use our project management team to project manage this so that we've got the project management expertise from [LA2] and the understanding of where our procurement rules are, but also to build that expertise that would then allow us to do more in the future." [LA2]*

Given the seeming importance of key 'champions' for driving forward scheme developments (Hawkey et al., 2013), it is possible that, without addressing the problem of staff resource alongside enabling access to consultants and expertise, the extensive heat mapping and feasibility studies will not lead to project development, let alone longer-term strategic planning of DH systems.

Another barrier highlighted within the interviews centred on the fast-changing nature of UK national government policy. In the preceding years to this study, frequent changes of funding schemes and incentives for DH had undermined the development of schemes and had made long-term planning difficult. Given the complexity and long lead-in times of DH projects, the changes in support meant that schemes could be undermined after significant amounts of work had already taken place.

5.4. The role of non-local authority actors

Analysis so far has focused on the visions and development approaches of local authorities. This section considers the role of other actor-types involved in

[9] In contrast to HNDU's approach in England and Wales to focus on local level consultant reports, the Scottish Government has developed a heat-planning map for the whole of Scotland. Local authorities in Scotland can therefore access the heat mapping information at address-level resolution without needing to commission a consultant's study. However, similar to England and Wales, the capacities and resources available to local authorities are still constrained for using this information to deliver new schemes.

supporting or delivering DH development in the UK. Interviews were conducted with 2 regional authorities [RA1, RA2], a city-based housing association [HA], a gas distribution company [GD1] and two large energy companies [EC1, EC2] with some activities dedicated to developing DH. In this case, the perspectives of the housing association actor were linked closely to their local authority funding-driven approach and have therefore been presented in section 5.3.2. However, housing associations have also led scheme development themselves (e.g. Cube Housing Association, Glasgow (McCrone et al., 2014)). The roles of additional supporting actors were noted to ensure that these actors' perspectives were explored in later stages of data collection where possible.

Public sector regional authorities

The regional authorities played facilitating roles over a number of local authorities. This enabled pooling of resources and sharing of skills and experiences between local authorities. Both had conducted heat mapping across multiple local authority areas in order to support the process of project prioritisation. However, their support for development approaches varied according to their regional and organisational priorities. One regional authority had a focus on fuel poverty alleviation for residents. The other regional authority saw DH schemes as an opportunity to support economic growth in the region and supported a commercial development approach. The interviewee from this regional authority identified stimulating low-carbon economic growth as a key motivation for undertaking heat demand mapping and DH feasibility studies:

> *"At the moment [the RA] has four priorities of which one of them is to act as a facilitator for a low carbon economy. As part of that we're developing a low carbon investment pipeline. […] [The projects] are low carbon but they contribute to the growth in the economy."* [RA1]

Private sector actors

The two energy company actors described their activity on DH as focused on limited commercially viable projects or where they could meet their obligations under ECO.

> *"The analysis is primarily on the value of ECO. So it's talked of in the way that we know that it will give back benefits [to residents] but we have to be able to*

> *make it stack up financially through the ECO in order to be able to make it deliver those benefits."* [EC1]

The need for local authority leadership was highlighted as necessary to enable a transition from stand-alone, one-off projects.

> *"We understand the technical potential for district heating and providing and improving things like waste to energy district heating. We can see the technical case, but the commercial case really does require big deal collaboration between local authorities to really up the ante with regards to district heating in the UK."* [EC2]

The gas distribution actor recognised a "potential" role for DH in a future low carbon energy system, but despite possessing a skill set for installing and managing pipe infrastructures, the actor was not involved in the delivery of any DH projects. Instead, the research and innovation efforts of this gas distribution company focused on use of biogas within the existing gas network.

> *"District heating has got a potential role to play within that because actually we're going to need a wider portfolio of energy within the national and the local mix than we do at present. And, there is a role for district heating as one of the planks of that."* [GD1]

In general, the private sector interviewees highlighted the challenges of uncertainty and high risk surrounding the long-term future of DH in the UK. Projects needed to compete on an economic basis with the existing infrastructure of the gas network and individual building-level boilers. There was also no clear indication of the direction that future energy system developments would take in terms of the energy efficiency levels of buildings and the implications of this for the long-term heat demands upon which DH business cases rest. Uncertainty and risk was felt to be too high to make financial investments within the existing context.

5.5. Discussion

5.5.1. Mismatch between local authority visions and development approaches

These pilot interviews showed local authorities held multiple visions for DH that sought to deliver complex forms of value across a range of economic, social and environmental objectives. Local authority actors used their visions for DH to address key local concerns such as local political priorities and mandated responsibilities. In the context of austerity and cuts to local authority budgets, this could be seen as a bid for a stake of the limited staff and financial resources to be dedicate to DH development activities. This tailoring of visions to local political priorities supports the suggestions made by Berkhout (2006) that visions are resources that are deployed by actors to influence the direction of change in a particular context. This contrasts with the concept of visions used in transitions management, where they are seen as independent of the actors and system in transition (Loorbach and Rotmans, 2006; Kemp et al., 2007).

In practice, the interviewees did not have the agency to act directly according to their articulated visions due to limited staff and financial resources. Although actors often recognised and articulated a need for a 'strategic' development approach to deliver their visions, their existing agency to lead such an approach often restricted them to taking funding-driven or commercial approaches, focusing on the development of stand-alone schemes with the hope that these would expand and interconnect at a later point.

The local authority interviewees in this study were largely reliant on support from national government to address resource and skills gaps. However, it did not appear that national government support mechanisms seeking to address some of the challenges faced by local authorities were succeeding in their objectives. Support through HNDU aimed to tackle the lack of expertise in local authorities, but the restricted focus of HNDU funding on consultancy expertise, without simultaneously developing internal local authority capacity and expertise. This was cited as a hindrance to developing a strategic approach to DH.

As was discussed in the case study presented by Eames et al. (2006) about visions for the hydrogen economy in London, this pilot study demonstrates how the articulation of visions is ultimately shaped by the dominant power structures and access to resources. Moving beyond the current opportunistic approaches of commercial returns or grant funding towards more local strategic coordination of DH development is a key theme that both local authority and non-local authority actors identified as important for enabling more widespread uptake of the technology and achieving its broad range of benefits. This requires a transition towards empowered local authorities with the appropriate capacities and powers to be able to deliver their strategic ambitions. A key theme for exploration within later empirical chapters and further discussion is therefore:

> What governance measures might allow actors to build up the agency to establish and deliver more radical visions of change?

5.5.2. Identifying the focus of further research within the thesis

The overarching research question of this thesis asks how the experiences of DH development in Great Britain can offer lessons for governing a transition to DH. Based upon this initial exploration of the case study, which offered insights into the drivers, visions and challenges of key actors involved in DH development in Great Britain, three specific areas for further and more focused study to address the research question were identified. The first two areas were specific governing measures that were being used by actors within the case study to support the DH development process across local areas (heat maps and intermediary activities). The third area was the challenge of actor agency within the DH development process. As was outlined in chapter 1, the literature on governing niche processes to drive socio-technical transitions is used as a theoretical basis to explore these areas in more detail. In particular, the concepts of shielding, nurturing and empowering processes (Smith and Raven, 2012). The three identified areas for further research, and their connection to the case study, are discussed in more detail below:

1) Heat maps were a simple form of tool applied in the early stages of DH development within the case study. The funding support available from HNDU had enabled a large proportion of local authorities to have access to

such a tool, and publicly available heat maps were also available online. In this study the heat maps were predominantly used to prioritise initial projects using techno-economic criteria to identify commercially viable schemes (supporting the commercial development approach). Chapter 6 explores the role and effectiveness of these heat maps in supporting niche processes in the case study. In addition, an example heat map is developed that seeks to better support niche processes and enables consideration of broader objectives beyond commercial viability.

2) The need to build actor networks to support the DH development was another key challenge identified within the pilot study. These networks played multiple roles, from transferring knowledge and best practice between local areas, pooling capacities and resources, and coordinating multiple local actors to enable cooperation for project delivery. For example, the traditional energy system actors interviewed within the study (represented by the energy company actors) highlighted their need for local authorities to give a lead to enable a more commercially attractive case for DH. The housing association actor was also looking to their local authority to offer the leadership to enable projects to be taken forward. However, lack of resource and capacity within local authorities to provide this coordination was a key barrier to a transition to DH taking place. Chapter 7 explores the role of intermediary activities in supporting niche processes for sharing learning and best practice within and between local niches. It draws on the existing literature on the role of intermediaries for delivering nurturing niche processes, and contributes further to this body of literature by exploring the role of intermediaries in delivering empowering processes as well.

3) Finally, chapter 8 focuses explicitly on the influence of actor agency over delivery of niche processes. A key theme arising within the pilot study was the lack of agency of local authority actors within the incumbent UK energy system regime for taking the strategic development approach they desired to deliver their DH visions. In the context of fast changing government

energy policy priorities and short-term funding cycles, public and private sector actors alike were unable to develop a long-term approach to DH. As a result they focused on small-scale, stand-alone DH projects with no clear mechanism for affecting more radical forms of change to enable large-scale development in the long term. The final results chapter (Chapter 8) explores the impacts of regime resistance on actors' abilities to deliver niche empowering processes within the case study.

5.6. Chapter conclusions

This pilot study highlighted the potential capacity of local authorities, situated within the public sector, with an ability to link multiple forms of value and to link up local actors to support the strategic development of DH. In the context of Great Britain, this could mean moving beyond just the most commercially viable schemes to seek wider benefits around economic growth and carbon reduction.

Within the pilot study, local authority visions for DH were shaped by their specific local context and sought to realise a broad range of social and environmental benefits as well as financial drivers. It is often recognised that DH, as a decentralised energy technology, needs to adapt to the local physical and technical context, but these local differences in social and economic circumstances are not commonly considered in the development process.

Interviewees highlighted a need for a strategic development approach to enable delivery of their complex visions for DH, but actors' agency to deliver this type of approach was restricted due to challenges such as lack of resource and capacity. Instead, actors resorted to funding driven or commercial approaches to deliver stand-alone schemes with the hope of expansion at a later point. Existing policy measures went some of the way to addressing local authorities' lack of experience and expertise in DH development, but the narrow focus on stimulating commercial viability of projects made it difficult to develop longer-term capacities to achieve wider objectives with DH.

Based upon this analysis, aspects of the case study have also been identified that offer an opportunity to contribute lessons for governing a transition to DH. These

have been identified as: the role of heat mapping tools in supporting niche processes (chapter 6), capacity building and knowledge sharing through intermediary activities (chapter 7), and the influence of actors' agency over the delivery of niche processes (chapter 8). The following chapters therefore continue with a more in depth investigation of these aspects of the case study.

6. Heat mapping as a measure for governing a transition to district heating

6.1. Introduction

Responding to the areas of interest identified within chapter 5, this chapter focuses on the use of heat maps as a potential measure that could contribute to governing a transition to district heating (DH). The chapter is presented in two parts. Drawing on relevant literature on governing socio-technical transitions, and using a conceptualisation of DH development in Great Britain as taking place within niche spaces, the first part of the chapter explores how heat mapping is used by a range of local and regional authorities within the case study as a means of facilitating DH development. Based upon this empirical study, lessons are drawn for governing a transition to DH more broadly. The second part of the chapter moves away from qualitative research and presents the design of a practical heat mapping tool which responds to recommendations for tool design made within the first half of the chapter. The tool aims to better support DH development within the context of Great Britain, specifically for projects seeking to alleviate fuel poverty. Advantages and disadvantages of the example tool are discussed.

6.1.1. The use of heat maps to inform decision making for DH

Heat maps provide spatial information about factors that influence the viability of DH networks. They map a range of spatial data sources such as estimated heat demand density, the locations and capacities of existing heat sources, as well as non-technical indicators such as fuel poverty or income segments, building types (domestic / commercial / public), or building ownership (privately owned, private rented, social rented).

Heat maps can be used for two purposes:

(1) At the early stage of development, to inform the identification and prioritisation of potential DH projects for developing further with detailed feasibility studies;

(2) And / or for strategic heat planning, to identify strategic areas for DH development to enable greater system benefits over the long term.

The process of heat mapping for project identification seeks to reduce the uncertainty that surrounds making an investment of resource in developing a project up to an investable standard. Figure 8 shows the DH development stages as an iterative process to identify a potential project and to reach delivery and operation. Heat mapping tools are used for this purpose at the early stages of project development when uncertainties around projects are high.

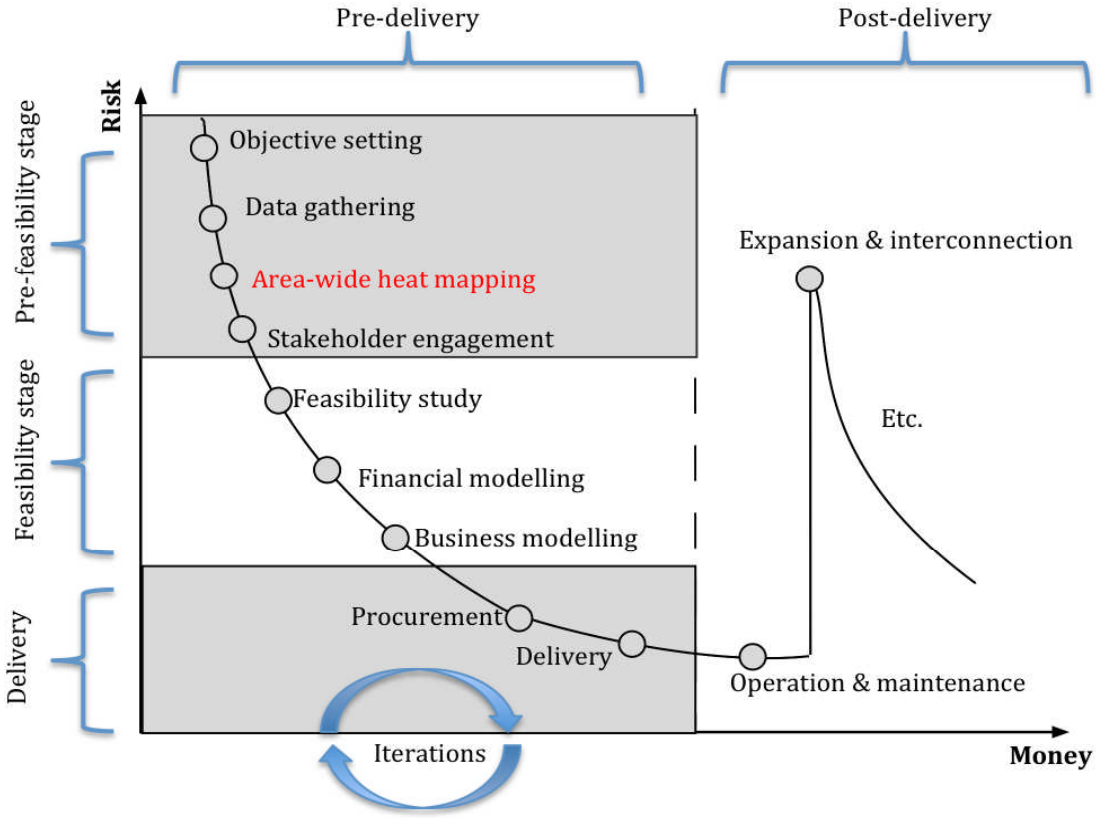

Figure 8: The project development process of a DH scheme, "illustrating how the risk of project failure should reduce as the project proceeds through the stages of development." Indicated in red is where area-wide heat mapping is undertaken during the pre-feasibility stage (diagram adapted from King and Shaw (2010))

Heat mapping tools can also be used to inform strategic energy planning. They enable energy planners to identify which technology solutions are most

appropriate across a given area. For example, in Denmark, a country with a high penetration of DH (67% in 2011(Euroheat & Power, 2013)), municipal authorities undertake heat planning, which is enforced through the designation of DH 'heat zones'. Within these areas, heat customers can be compelled to connect to a DH network, thereby significantly reducing the risk associated with making the initial capital investment for a DH company to develop a new network (Chittum and Østergaard, 2014). The EU Energy Efficiency directive (Article 14) has also enforced each EU member state to create of a form of heat map as part of undertaking a comprehensive assessment of their potential for efficiency in heating and cooling (EU, 2012).

6.1.2. Heat mapping in Great Britain

Recognition of the potential of DH for meeting multiple energy challenges within Great Britain has led to increased interest and support for heat mapping activities. Local authorities have been highlighted by the UK and Scottish governments as key actors that can play a strategic coordinating role and potentially a delivery role in projects (DECC, 2013c; Scottish Government, 2015). As a result, both the UK and Scottish Government actively encourage local authorities to make use of heat maps.

> *"Heat mapping is a powerful way to visualise opportunities, to assess who needs heat (demand) and where sources of heat might come from (supply), and how these can be connected in an efficient way to reduce the cost of heat supply and the carbon intensity of heat generation. It can also be used, in combination with other spatial datasets, as a tool to focus on areas of need or priority."* (Scottish Government, 2013)

In England and Wales, the Heat Network Delivery Unit (HNDU) was set up within DECC to offer support to local authorities in their work on DH. As part of the unit's work, local authorities could apply for a portion of £7 million to support their work on DH development up to the investment stage of a project. This includes heat mapping, and 70 out of 115 successful local authorities were funded for this purpose (accounting for 9% of allocated HNDU funding) between 2013 and 2015 (Personal communication with HNDU and report by CAG Consultants, 2015). In

Scotland, the Heat Network Partnership offers support to local authorities in their use of the Scottish Heat Map.

Previously, the focus on gas and electricity in the UK has meant that heat maps have not been part of energy system development and planning. Therefore, compiling relevant and accurate data can be challenging and time consuming, and sometimes the data needs to be estimated using modelling. The UK Government's Department of Energy and Climate Change (DECC) commissioned development of a basic heat map for England (DECC, 2012b) to begin to overcome this issue. Data from the map can be viewed spatially online and its data is shared with local authorities through the public sector mapping agreement. It includes data on estimated heat demand (divided in public sector, commercial, industrial and residential heat demand categories), along with data on existing CHP plants and thermal power plants. Data on water source heat potential was also added after data collection for this study took place. Similarly, the Scottish Government developed a heat map for Scotland (Scottish Government, 2012), granting access to local authority officers to higher resolution data sets, as well as wider public data sets at a lower resolution.

6.1.3. Research questions

Given the time and financial resources invested in heat mapping tools within the case study, both in national level tools and local data collection and analysis, it is important to understand how and where heat mapping tools play a role in governing a transition to DH within the case study and where there are lessons for governing a transition to DH more broadly.

As has been discussed in previous chapters, the case study of DH in Great Britain represents the early stage of a transition where actors involved in project development seek to create supportive local conditions that enable successful delivery of new networks. Therefore, the literatures on the role of niches in driving a transition present a useful theoretical basis for shaping the analyses conducted within chapters 6, 7 and 8. The DH development process is conceptualised as a process of niche creation and development. This chapter draws on the relevant literature for governing niche processes set out in chapter 3, and in particular the role of niche shielding, nurturing and empowering processes (Smith and Raven,

2012), to consider how heat mapping is used to drive a transition to DH within the case study. Since the local actors utilising heat mapping tools in the case study have limited powers to introduce shielding measures, the analysis focuses primarily on niche nurturing and empowering processes.

Based upon this analysis, **Part 1** of the chapter considers what lessons can be drawn for governing a transition to DH in terms of supporting nurturing and empowering processes with heat mapping. In particular it considers how heat mapping tool design and functionality could better support these processes.

The majority of the research presented within this thesis focuses on governance recommendations drawing from socio-technical theories. However, these recommendations are not often tested in practice within the research process, and may face unexpected challenges when being implemented in the context of the incumbent regime. **Part 2** of the chapter therefore takes a different focus to other parts of the thesis. It explores how a heat mapping tool could meet the recommendations from part 1 of the chapter, and discusses the potential challenges of developing and implementing this in practice. In particular, it uses the example of a heat mapping tool aiming to support development of DH for fuel poverty alleviation.

In summary, the following research questions are addressed within the chapter:

Part 1:

1. How does heat mapping support niche nurturing and empowering processes within the case study?
2. What lessons can be drawn from analysis of this aspect of the case study for governing a transition to DH?
    a. In particular, how can heat map tool design and functionality support niche processes for governing a transition to DH?

Part 2:

3. What is a potential methodology for designing a heat mapping tool for the purpose of supporting niche processes
4. What are some of the practical challenges that face development of heat mapping tools for this purpose?

The rest of the chapter is structured as follows:

Part 1

Section 6.2.1 outlines the theoretical literature used in the chapter, including wider literature on tool-use in policy making. Section 6.2.2 presents the analytical approach used to explore the empirical data; section 6.2.3 gives an overview of the empirical qualitative data used in the study and discusses the data collection methods used; section 6.2.4 presents the results of analysis of the data to show where heat mapping tools are currently supporting delivery of nurturing and empowering niche processes; section 6.2.5 discusses these results in relation to th2 literature on tool-use in policy making, and 6.2.6 then goes on to draw lessons from the study for governing a transition to DH in general.

Part 2

In part 2, section 6.3.1 outlines the heat mapping tool design and methodology (a more detailed methodology for the tool is presented in appendix E) and section 6.3.2 discusses how broader social and governance criteria were incorporated into the tool. Section 6.3.3 presents and discusses 2 scenarios of different weightings applied to an example of the town of Cheltenham. Section 6.3.4 discusses how the publically available tool has been utilised by stakeholders and makes suggestions for further work. Finally, section 6.4 summarises the key contributions in the chapter to the thesis research questions.

6.2. Part 1: Lessons for the use of heat mapping as a measure to govern a transition to DH

This section presents part 1 of the chapter, which explores how heat mapping tools are used to support niche nurturing and empowering processes within the case study. Based upon an analysis of empirical data from local and regional authorities within the case study, lessons are drawn for approaches to governing a transition to DH.

DH development is conceptualised within the study as a form of niche creation. As outlined previously in chapters 1 and 3, the formation and development of niches can play a crucial role in driving a transition to a new socio-technical regime (Kemp et al., 1998; Kemp et al., 2007). Smith and Raven (2012) set out the concepts of niche nurturing and empowering processes as important aspects of consideration for governing a transition. Niche nurturing processes facilitate development of actors' capacities and networks to enable application of an innovation. Niche empowering processes support the diffusion of an innovation beyond the protected niche space.

This chapter considers heat maps as a form of decision support tool. Decision support tools are a means of providing and structuring evidence to inform actors' decision making. Tools can vary in their levels of sophistication, from simple tools which consist of checklists or process steps that frame a decision, through to advanced computational modelling tools which aim to offer understanding on more complex system dynamics (Nilsson et al., 2008).

The socio-technical transitions literature does not yet explicitly consider the role of decision support tools in niche creation. However, tool-use for decision making has been considered extensively in other areas of the literature (Hughes, 2013; Nilsson et al., 2008; Radaelli, 2004; Radaelli, 2005). This chapter therefore draws on aspects of other bodies of literature to inform analysis and discussion. Specifically, it draws on the literature on bounded rationality in decision making, and the influence of context on tool-use in policy making. Relevant parts of this literature are outlined in the next section.

6.2.1. Part 1: Theoretical basis - Tool-use in decision making

The theory of bounded rationality challenges the idea often assumed within economic theories that decision making is a linear, rational process that selects the optimum action given all relevant information (Gigerenzer and Selten, 2002; Simon, 1955; Simon, 1957). Instead, bounded rationality recognises decision making is shaped by the limits of actors' cognitive capacities to gather and compute information; as well as the structure of the environment in which the decision is being made (Simon, 1957). Heuristics are used to overcome the challenge of decision making in the context of "limited time, knowledge and other

resources, in a world that is uncertain and changing" (p10. Gigerenzer and Selten, 2002). They are established based upon social norms and imitation of other actors within the environment (Simon, 1957). Therefore, when considering the role of decision support tools, it is important to consider the place of decision support tools within actors' bounded rationality.

Study of tool-use in policy making has highlighted the effect of bounded rationality on the way tools are used in practice. Numerous tools have been developed to support the policy making process across different policy arenas. In particular, the advancement of computing power in recent decades has enabled an increase in the number and range of modelling tools being developed (Keirstead et al., 2012). However, there are often problems of tool non-use, or where tools are used, they are often applied for politically motivated reasons to support an existing preference (Nilsson et al., 2008; Radaelli, 2004).

For example, Radaelli (2005) reviewed applications of Regulatory Impact Assessments (RIA) across EU countries (a form of tool to help decisions on regulatory approach). Although numerous countries incorporated use of RIA tools into their policy processes during the 1990s, the ways that it was applied varied from country to country. Radaelli (2005) points to the influence of political context for explaining these differences. He argues that a tool's legitimacy must be established within the policy process to enable it have an impact. This requires a government to possess the capacity to establish "acceptable" answers to the questions: "Who sets the assumptions within decision support tools? How are they designed? Why should the process be considered legitimate to all stakeholders?" (p.932, Radaelli, 2005). The application of tools can differ depending on when they are being used within the policy process and who is using a tool. For example, a politician may be looking to establish a consensus across stakeholders, or an economist may be concerned about efficiency (Radaelli, 2005). The existing policy culture in a country determined the point in the policy process where a tool could be applied. For example, Denmark used RIA early in the policy process to increase dialogue and build consensus across actors. France and Germany, on the other hand, used RIA at the end of the policy process to add legitimacy to a decision that had already been made. The RIA tool was designed with assumptions that suited

the dominant political approach for those governments. Consideration of tool-use as a form of transition governance measure therefore needs to consider the political and institutional context of where niche creation is taking place.

Nilsson et al. (2008) consider the growing use of policy assessment tools in ex-ante policy making. They consider the range of tools, from simple to sophisticated, that are used within case studies from the UK, Sweden, Germany and the European Commission, to assess in which contexts different types of tools are most influential to the policy making process. They highlight how, within their case studies, tools were "likely to be selected primarily on the basis of organisational routines and standard practices, and on the expectation that they will produce evidence that speaks directly to, and supports, the core beliefs of governing coalitions" (p.352, Nilsson et al., 2008). They found that actors particularly made use of 'simple' tools because they had more predictable outcomes that actors could anticipate and use when it supported their agenda. Tool use was also encouraged by actors seeking to have involvement in, and influence, the policy process. They would develop forms of policy assessment tools as a means to legitimise their place in the policy process (Nilsson et al., 2008). These findings highlight how actors are unlikely to voluntarily embrace the use of a particular tool unless they feel it will support their current agenda and objectives.

6.2.2. Part 1: Analytical approach

In order to address the research questions within this chapter, niche nurturing and empowering processes are explored using a framework based upon the concepts of strategic niche management (Kemp et al., 1998). As outlined in detail in chapter 3, strategic niche management is a means to create a protective and supportive niche environment that enables actors to experiment with and develop an innovation to demonstrate its viability for widespread uptake (Kemp et al., 1998). In the terminology used to describe governing of niches by Smith and Raven (2012), strategic niche management is a form of niche nurturing process.

Considering the three objectives of strategic niche management, summarised by Schot and Geels (2008) for strategic niche management, it is possible to conceive of a potential contribution of decision support tools for each of these aims:

1. **Development of a network of actors to support the technology** – Decision support tools could be used to help instigate and structure dialogue between key actors, building understanding and establishing a consensus on the need for actions.
2. **Improvement in the required skills and technology adaptations for widespread uptake of the technology** – Decision support tools could be used to support inexperienced actors to perform activities such as technical analysis or system planning. This could drive technology adaptations and improve the skills of key actors.
3. **Understanding of the technology's values** – Decision support tools could demonstrate the potential benefits and impacts of a technology before it has been implemented.

In addition, the work is concerned with exploring approaches to delivery of niche empowering processes. A fourth objective is therefore added for consideration:

4. **Delivering empowering processes for wider system change** – Decision support tools could provide evidence for wider system change, for example by highlighting the links between an innovation technology and the wider energy system.

The examples given here are by no means exhaustive, but are included to illustrate the potential of decision support tools for supporting the process of strategic niche management.

Analysis of the empirical data was conducted using a method of thematic analysis (Braun and Clarke, 2006), using an initial phase of coding structured according to these four objectives to explore the role of heat mapping in supporting niche nurturing and empowering processes. Based upon this analysis, the discussion in section 6.6 draws on the literatures on tool-use in policy making to consider how tool-use was being affected by bounded rationality of actors and the context in which they were working. Lessons are drawn for the use of heat mapping as a measure to govern a transition to DH.

6.2.3. Part 1: Empirical data

The analysis in this chapter focused solely on UK local authorities' use of heat mapping. Local authorities are not the only actors that might make use of heat mapping tools. However, their key coordination role within the DH development process means that they offer a useful focus for this analysis. They have also been actively encouraged and supported by the UK and Scottish governments to use heat mapping tools in their work on DH.

The chapter builds on work undertaken during a research project supported by the Chesshire-Lehmann Fund[10], which the author co-delivered with two other researchers. The project made an initial exploration of the role of heat mapping tools in supporting DH development for the purposes of alleviating fuel poverty (Bush et al., 2014). Data collected within this Chesshire-Lehmann funded project formed part of the first phase of data collection within the thesis. A detailed description of the project and its link to the work in this thesis is included in chapter 4.

This part of the chapter uses empirical data from 11 UK local authorities and 3 regional authorities to inform analysis of heat mapping use to support niche processes (an aspect that was not explored within the Chesshire-Lehmann work). More details of data collection are outlined in section 6.2.3.

The data used in this chapter was sourced from all three phases of data collection conducted for the thesis (c.f. chapter 4), drawing on data from local and regional authority actors. Phase 1 of data collection formed the initial basis of the analysis, using semi-structured interviews with 5 local authority actors and 2 regional authority actors. These sets of interviews had a specific section dedicated to the functionality and application of heat maps. Appendix D details the specific heat mapping-related questions used within these interviews. In addition, data from phases 2 and 3 of data collection were also included where use of heat maps was

[10] The Chesshire-Lehmann Fund was set up to support research into issues surrounding fuel poverty (http://www.chesshire-lehmann.co.uk). It is administered by the charity National Energy Action. The project funding of £5,000 covered costs of travel for conducting interviews, interview transcription, the creation of a video to communicate the results of the research to relevant stakeholders, and contributed towards the costs of creating an online mapping tool.

discussed as part of wider conversations (within the decision theatre for phase 2 data and within semi-structured interviews in phase 3). Although specific questions related to heat mapping were not included as part of phases 2 and 3 of data collection, use of heat mapping tools was a recurring theme within answers to non-heat mapping related questions. The questions used to structure interviews within phase 3 of data collection can also be viewed in Appendix G. In total, data from 11 local authority actors (5 from Scottish local authorities [Coded as: SLA1, SLA2, SLA3, SLA4, SLA5] and 6 from English local authorities [Coded as: ELA1, ELA2, ELA3, ELA4, ELA5, ELA6]) and 3 regional level authorities were included in the analysis [Coded as: RA1, RA2, RA3]. Data included in the study was collected between May 2013 and August 2015.

As has been outlined previously, actors were selected who took a lead or an active role on DH within their local authority, and had begun to engage with heat mapping activities. A range of experience levels were sought, to ensure there was representation within the data set of actors with operating DH schemes through to those at the early stages of developing a project..

6.2.4. Part 1: Results

This section presents results of the thematic analysis conducted on the data set. The role or functions of heat mapping tools were explored for each aspect of the analytical framework. Table 5 summarises the identified roles and functions that heat mapping tool use is making to these aims in the case study. The following sections presents the identified themes and accompanying evidence for each aspect of the table.

Table 5: Summary of the applications and uses of heat mapping tools for achieving the aims of strategic niche management in DH development in the UK

Establishing new actor networks	Skills and technology improvement	Demonstrating technology value	Delivering empowering processes
Stakeholder identification; Stakeholder engagement.	Introducing the DH development process to new actors with a structured activity; Increasing actor confidence	Evidence base from heat maps reduced uncertainty about project techno-economic viability Inclusion of relevant data sets enabled heat maps to consider social and environmental benefits alongside techno-economic viability.	Evidence base to inform planning of a strategic approach to DH development, expansion and interconnection.

Establishing new actor networks

Building strong local actor networks, initially reliant on trust and cooperation were seen as a crucial part of the DH development process. Project plans often relied on a small number of large anchor loads that provided the basis for a reliable and predictable business case. Stakeholder engagement was therefore an important part of the development process, to build up a trusted commitment to a project and enable development of an investable business case

> *"There is always an inherent risk in the process, […] because for instance, your stakeholder suddenly says he's not interested in being involved in that…and he was going to take 75% of your heat. So it can die a death there."* [RA3]

Actors within the study used the outputs from heat map analyses, as well as the data collection process undertaken to feed into heat maps, as a basis for stakeholder identification and engagement. The process acted as a mechanism for a focused approach to stakeholder engagement with key stakeholders such as

managers of sites with large heat demand loads that might act as key anchor loads for a scheme. The data collection process in particular helped to initiate conversations.

Heat maps were also used as a communication tool within the stakeholder engagement process, providing a visualisation of the potential opportunity to actors who could be unfamiliar with the technology. This visual tool enabled dialogue and building of mutual understanding about the priorities and constraints of other actors.

> *"It's an incredibly visual thing. […] To have everybody round the table and have a visual tool which shows them exactly where they are, spatially in relation to everyone else and everybody else's agendas. […] The links were very obvious within this."* [SLA3]

They were also seen as useful for promoting DH opportunities to potential private investors.

> *"Our colleagues in economic development and planning can see the benefits of [the heat map] and how we could really use it as a tool to attract investment in the city."* [SLA5]

A challenge for utilising heat mapping tools for stakeholder engagement was that this function relied upon local authorities having sufficient staff resource and skills. Contacting stakeholders for data collection took up large amounts of actors' time and data was often inaccessible for reasons of commercial confidentiality or lack of trust.

> *"A constraint is to actually find time to use the tools. We have used some of the modelling tools in the past but normally just gotten in student expertise or student labour in to help with using some of them. Sometimes we use consultants to use them for us as well."* [ELA2]

> "*Even some big public sector organisations are reluctant to tell you what their building consumption is. It is nuts."* [ELA1]

Commissioning of consultants was used to overcome these resource constraints. Conducting mapping exercises over a regional scale, combining several local authority areas, also offered resource savings for individual local authorities. However, in-house resource was still needed to maintain momentum over the long development time of DH projects.

> "*You do want to maintain an element of in house, if you're going to be able to sustain it."* [ELA2]

In addition, identification of key stakeholders was often a balance between the evidence provided by the heat map and local knowledge of the risks of working with particular partners. Knowledge of the political context and stakeholders' attitudes towards DH often formed the strong influence over project prioritisation, over technical outputs from the heat map. For example, public sector heat loads were often prioritised because of a perception that there was more potential to influence their decisions than private actors.

> *"So the very first thing is that quick technical field, to make sure that you've got enough heat density in the area. Then I suppose it is looking at knocking out some of the barriers […] How much does the council own? How much can we guarantee that we can connect to? Then I suppose, looking at other heat in the area."* [ELA2]

Without embedding capacities for making use of heat mapping tools within the local authorities, this need for combining technical information with knowledge of the local context is more difficult to achieve.

Skills and Technology Improvement

Heat maps offered a form of learning to local actors engaging with DH for the first time. They offered an initial structured activity for local authority officers to begin to build up their understanding and confidence, and the mapping outputs provided an easily understandable, visual representation of the DH potential across a given area.

> *"It's building confidence isn't it? We know we've got some resource, but is it that or is it that?"* [ELA1]

The levels of uncertainty associated with the technology caused debate about the required level of data detail and heat map functionality. Some actors wanted increased heat mapping functionality to gain an earlier indication about whether a project was going to be financially viable. They were looking for ways to reassure themselves that the time and financial resources they were investing in developing a project were likely to be successful in the end.

> *"It would be absolutely fantastic if you had a tool that was fairly straightforward to use, and used data that was granular enough, that you could plan a network […] with some payback and carbon savings, and revenue generation and basic IRR, and net present value."* [ELA1]

However, other actors suggested that this was not realistic at this stage in the development process.

> *"I think at this stage, if you did go down to the nitty-gritty, what value would you place on those figures? They would be plucked out of the air because you are at such an early stage of feasibility."* [RA3]

The skills required to be able to use heat mapping tools for any of these purposes was another important influence over the extent and manner of tool use. Local authority officers leading on heat mapping for DH did not always have access to staff with Geographical Information Systems (GIS) skills. This made interrogating heat mapping tools without the help of consultants difficult.

> *"Currently in the public sector there are major cuts. Front line schools and social care are unlikely to be cut, but back office services, which might include people who look at GIS and do those sorts of things, are highly likely to be cut. So even in the time I've set up the project up, I have had a huge turnover of key officers. So even the ones I trained up and got interested have moved on in some cases already, and I have only been in eight months"* [RA2]

Demonstrating technology value

Actors saw heat mapping tools as a potential source of evidence to inform prioritisation of project opportunities, building business cases and persuading relevant stakeholders of the potential opportunity presented by a project. This was a form of prospective demonstration of technology value.

> *"I think it gives you more evidence, and evidence is useful if you're writing applications and trying to make a business case"* (ELA5)

However, the effectiveness of heat mapping tools for demonstrating DH technology value was limited by the functionality of the tool and the credibility and resolution of heat map data. For example, eligibility of projects for funding support was an important consideration within the project prioritisation process that was not always included as a data set for heat map analysis. In dense heat demand areas, high data resolution was needed to be able to make useful project prioritisation and stakeholder identification decisions. However, for reasons such as data gaps or commercial sensitivity of data, this detail was not always available and had to be modelled or assumed.

> "*Getting down to the building level data is impossible. […] DECC have talked to the Big 6, but you just can't get to that level of detail to be able to just put it up on a map and say, 'if you target these buildings…' "* [ELA1]

Data accuracy was also a problem for heat demand in fuel poor households, where occupants were known to under-heat their homes. Within an analysis based upon heat demand density, an area with high levels of fuel poverty could seem less economically-suitable for DH than if occupants were able to afford to use the level of heat they needed. This could also have an impact on system sizing in later stages of project development in areas of high fuel poverty, where heat demands could change depending on the affordability of the heat price.

As was explored in Chapter 5, many local authorities' drivers and visions for DH focused on exploiting these potential wider benefits of DH. However, although heat maps had the potential functionality to explore these wider types of value, the maps developed for local authorities did not always include relevant sets of data,

and instead, they focused on techno-economic criteria alone[11] (estimated heat demand density, existing heat supply sources, highlighting large heat demand users). 'Best practice' guidance from HNDU also did not encourage consideration of these wider factors in any explicit way. Guidance for the fund states that bids from local authorities are assessed on "local authority capacity and commitment and whether the project is likely to become a credible prospect for commercial/ financial development." (p.14, DECC, 2014).

Delivering empowering processes for wider system change

Heat maps had the potential to support niche empowering processes by providing an evidence base for long-term strategic DH plans across a district. For example, Denmark uses an approach of DH 'heat zoning', where local authorities hold powers for designated heat zones to require connections to schemes if necessary. These powers enabled Danish local authorities to plan where DH was most useful for the energy system over the long term and ensure implementation of these plans (Chittum and Østergaard, 2014).

Analysis of this UK case study showed that although heat maps were not currently used to their full potential, some local authority interviewees had begun to use heat maps to inform planning policy for new developments. Use of the maps for planning policy enabled DH planning to be linked with new-build developments, highlighting opportunities for expansion and interconnection with existing schemes. This approach sought to use new-build developments as a catalyst to enable expansion of networks to retrofit areas at a later point. In addition, energy masterplanning exercises for specific areas of potential were also informed by data from heat maps.

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[11] In Scotland, where the political priorities for heat policy focused strongly on fuel poverty, the functionality had been built into the Scottish Heat Map and consideration of these factors alongside techno-economic considerations was beginning to be actively encouraged.

However, even this restricted form of strategic planning for DH, focusing on planning policy for new builds and energy masterplanning for specific sites, proved challenging to deliver in practice. For example, actors often struggled to write planning policies of sufficient strength to require installation of schemes.

> "*We really don't have [the ability to require developments to implement DH] yet. We could write a policy saying it is a requirement and you must do it. That's probably a challengeable policy if we were to write it in that way. So at the moment what we are doing is encouraging and trying to cajole them, rather than require something to happen."* [SLA3]

There were no activities that supported strategic planning for retrofitting of schemes. As a result, retrofitting projects were mainly limited to social housing and public sector buildings where there were large heat loads and local authorities had existing relationships and influence with decision makers.

6.2.5. Part 1: Discussion

This section returns to the chapter's research questions to discuss (i) the role of heat mapping tools for supporting niche nurturing and empowering processes within the case study; (ii) lessons for how heat mapping tools can support governing of a transition to DH in general. The following sections discuss the findings and lessons from the analysis first for nurturing processes, followed by empowering processes. Finally, section 6.2.6 considers lessons from the analysis specifically for heat map tool design to enable them to better support niche processes.

The contribution of heat maps for supporting nurturing processes

The role of heat mapping tools for supporting niche nurturing processes was explored through considering a framework for strategic niche management. The analysis showed that heat maps could provide an evidence base to demonstrate the technology's value to stakeholders, who were often unfamiliar with its capabilities. They could help to identify where stakeholder engagement needed to take place to build supportive actor networks around the technology. Heat maps could also support learning processes by providing a structured activity to increase niche actors' understanding of the technology.

In general, heat maps provided an evidence base to inform and support decisions on project prioritisation, often demonstrating the technology's techno-economic potential. Unsurprisingly, actors considered factors that were not reflected in their heat maps, and decision making also relied on a significant element of knowledge about stakeholders' existing attitudes, the state of existing relationships and their attitude to risk (a demonstration of the importance of context and bounded rationality in decision making (Gigerenzer and Selten, 2002)). Heat maps were not the sole basis for project prioritisation and in some cases had little influence over the final outcome.

Where capacities and skills to use the heat maps were not available internally within local authorities, the reliance on external consultants meant there was potential for a disconnect between analysis and use of the heat map and knowledge of the local context and stakeholder relationships. A potential for increasing the relevance and impact of heat mapping tools for creating supportive DH actor networks lies with embedding the resources and skills to make use of them within local authorities, rather than relying on external consultant support.

Local authorities' capacities to utilise heat mapping tools to support nurturing processes varied and depended on local contextual factors. For example, use of detailed heat maps required access to GIS skills, staff resource and cooperation across local authority departments and external local stakeholders to enable inclusion of detailed and accurate data. These types of factors were largely determined by the historical context and priorities of the local authority as they had responded to budget cuts. Embedding use of heat mapping tools was therefore more challenging to achieve in some areas than others.

The functionality of the heat mapping tool determined the extent to which it could be used to demonstrate the range of values that might be sought from a DH project. As Nilsson (2008) points out, actors tend to use tools in policy making that "speak to the existing core beliefs" or the organisations and stakeholders they are seeking to influence. The choice of data considered within heat maps was therefore important for enabling the tool to be useful within the specific local context; enabling actors to prioritise projects and demonstrate the value of the technology

according to their own local priorities. However, the choice of data sets within heat maps was predominantly aimed at identifying the most commercially viable schemes, rather than considering local stakeholder priorities for DH.

Based upon these discussions, a recommendation to increase the impact of heat mapping tools for supporting niche nurturing processes would be: (a) ensure that a range of data sets that reflect criteria beyond techno-economic priorities are included within heat mapping tools to enable decision makers to explore multiple scenarios; (b) to develop a programme of support within local authorities around heat mapping tools to provide relevant skills to actors looking to make use of them; (c) as an intermediate step, develop a simple, easy-to-use heat mapping tool that enables interrogation of publically available data sets by actors without GIS skills. This would allow elements of heat maps to be explored and utilised not just by local authority actors with access to the right software and skills, but by wider set of local authorities and local stakeholders considering being involved in a scheme as a heat anchor load or heat supply source. A potential design for such a tool is presented and discussed in part 2 of this chapter.

The role of heat maps in supporting niche empowering processes

As demonstrated in countries such as Denmark, heat mapping tools have the potential to form an evidence base for local strategic planning for DH (Chittum and Østergaard, 2014). This type of strategic planning can be used alongside regulatory powers or incentives to drive development of large scale, interconnected networks that offer larger benefits for the wider energy system (Woods et al., 2005). Use of heat mapping for local strategic planning could therefore be seen as a form of niche empowering process within the case study.

The analysis here has shown that the application of heat maps within the case study for this purpose was mainly limited to informing planning policy for new build developments. Aside from this, local authority actors had little powers or capacities to deliver strategic plans for retrofit areas.

As Radaelli (2005) highlighted, the influence of tools within decisions is dependent on the legitimacy of the tool with the stakeholders acting upon its information. For example, it was important that stakeholders recognised a tool's assumptions and

criteria as appropriate for their local context. It appears that within the UK context, the legitimacy of heat mapping, and the role of DH in general, has not yet been fully established. As a result, local authorities making use of heat mapping to inform new build planning policy did not yet feel confident that they held a sufficiently robust evidence base that would enable them to require DH development within local planning policy. This concern was reinforced by cases of new-build developers seeking to challenge planning policy where it was in place.

One way to build up the legitimacy of heat mapping for informing local DH strategic planning would be to designate nationally recognised and transparent criteria for use in DH strategic heat planning. The formation of these criteria would need to take account of both local and national priorities and visions for DH to establish an acceptable balance for both local niche actors and national objectives. Some form of stronger enforcing powers for local authorities to enable delivery of these plans would also likely be required. However, in the context of fast changing national energy policy approaches, it is likely that establishing this kind of long-term approach could be challenging in practice in the context of resistance to change from established industry actors. This theme is picked up again in chapter 8, where the influence of regime resistance on actor agency is explored in detail.

6.2.6. Part 1: Lessons from the case study on heat map tool design and functionality for supporting niche processes for governing a transition to DH

The analysis has highlighted some of the challenges faced by actors seeking to develop DH in the context of a regime where it is not yet established within the energy system. In particular, local authorities seeking to utilise heat mapping tools to support the development process of projects had limited access to skills and resources to embed use of the tools into their approach. As was suggested in the previous discussion on the role of heat mapping to support niche nurturing processes, a simple tool suitable for use by actors without GIS skills, based upon publically available data sets, could serve many of the important functions of a heat mapping tool for supporting niche nurturing processes at the early stage of DH development.

In particular, it could be used to demonstrate the potential value of a DH network to local actors and support the stakeholder engagement process by enabling early identification of potentially important actors and informing early discussions of potential scenarios and priorities for DH. A key opportunity for heat map tool design adjustments would be to include a breadth of data sets into the tool to enable users to reflect the priorities of their local decision makers beyond techno-economic factors. Alongside wider inclusion of data sets, building in tool functionality that allows actors to subjectively weight each data set according to the local priorities, could enable exploration of a greater number of scenarios to inform strategic decision making beyond specific project development.

Such a tool could only act as a guide and stimulus for discussion at the early stages of planning, rather than forming the basis of an investment decision. However, this form of simple heat mapping tool could support development of skills, understanding and building of local actor networks from an early stage in the process and could embed the principles and skills for heat mapping for later phases of energy master planning and feasibility studies.

To summarise, part 1 of this chapter argues that there is potential to adjust the heat mapping tool design and functionality to better support the process of DH development and strategic niche managent. Such a tool should:

i. Be quick and simple to learn how to use, without requiring specialist GIS skills;
ii. Consider data sets that indicate wider types of value than just techno-economic indicators of viability, using existing and easily accessible data sources;
iii. Encourage dialogue between stakeholders during the project prioritisation process.

Incorporating these aspects into heat mapping functionality would enable local actors to adapt the mapping tools to their own context and embed them into their local decision-making process. This would also familiarise DH niche actors with this form of tool-use, to enable its application during later stages of niche development for long-term strategic planning for DH. The next section presents an

example of a heat mapping tool that was designed and developed to fulfil these principles, specifically considering development of DH for alleviation of fuel poverty.

6.3. Part 2: Developing a heat mapping tool to support niche processes in the case study

This part of the chapter demonstrates an example of a heat mapping tool design that can meet the specifications outlined in part 1 of the chapter. The design of the tool responds to the findings of part 1 of this chapter (presented in section 6.2.6) and specifically aims to help users to incorporate consideration of opportunities to reduce fuel poverty into their DH development process. The tool design is evaluated and some practical challenges that face development of heat mapping tools are highlighted.

6.3.1. Part 2: Summary of the heat mapping tool design

The heat mapping tool, called the Leeds Heat Planning Tool, was developed as part of the project exploring DH and fuel poverty funded by the Chesshire-Lehmann fund. The tool was originally developed within Microsoft Excel. However, using part of the funding from the Chesshire-Lehmann trust, combined with support from Energy Leeds impact funding, a software developer was commissioned to develop it into an interactive online version which can be viewed and used on the following website:

http://sure-infrastructure.leeds.ac.uk/leedsheatplanningtool/

(The online version of the tool was developed according to the tool design specified by the present author, with no input from the software developer into the tool's functionality).

The tool incorporates a range of publically available data sets covering techno-economic indicators, alongside wider indicators of project risk and also potential for social benefits from projects (data used in the tool is listed in Appendix E). The tool design provides the user with the means to incorporate multiple criteria into their heat mapping analysis by creating a score for the census output areas in a

given local authority. Users can choose which indicators to consider within the scoring process, and weight different factors according to their local priorities. The scoring is represented spatially with a thematic map, visualised in Google maps to enable connection with the geographical features of an area. Developing the tool in this way enables it to be open access online and does not require specialist GIS skills in order to use it. Figure 9 summarises the key stages in using the tool. Appendix E outlines in detail the method used within the tool.

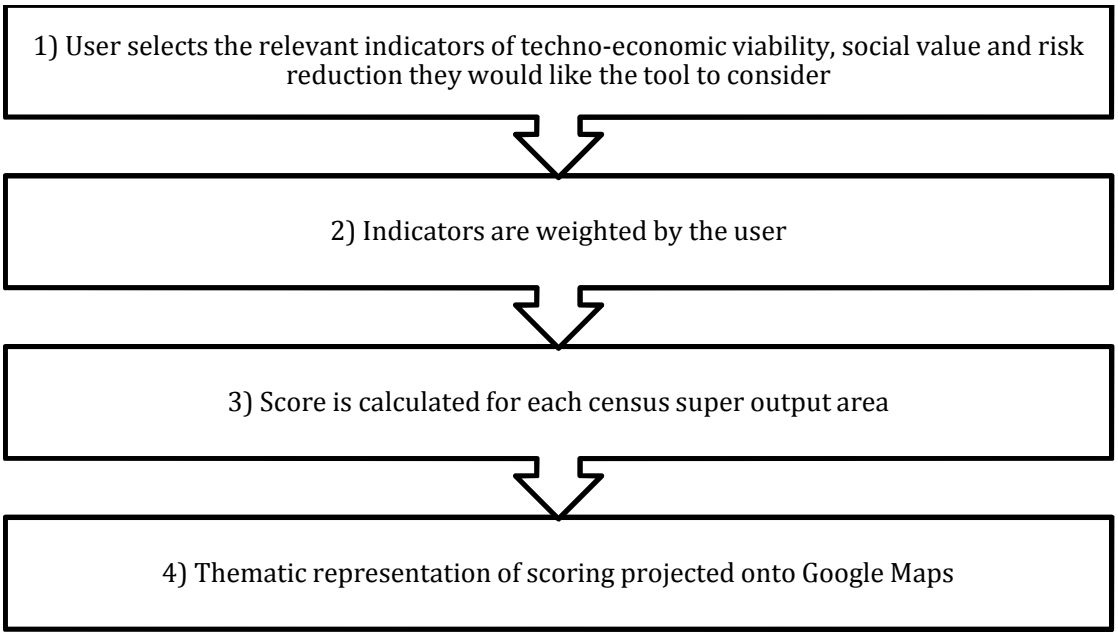


Figure 9: Overview of the user-process for the Leeds Heat Planning Tool

6.3.2. Part 2: Going beyond techno-economic data

The tool was designed to allow consideration of both techno-economic and social criteria. In order to select relevant indicators for local authority decision makers in England and Wales, these were identified based upon empirical evidence from the interviews with local authorities, and further verified with data from a local authority workshop discussion (Vanguards Network, 2013). This also enabled inclusion of some of the heuristics used by local authorities to overcome uncertainty within the development process. These have been labelled as 'governance' factors within the tool. Table 6 details the key indicators identified for inclusion.

Table 6: Three categories of indicators used within the tool: techno-economic, governance and social characteristics

Techno-Economic viability	Governance	Potential for achieving social value

Heat density
 	
Large heat demands
 	
Existing heat generation sources
 	
Sources of recoverable heat
 	
Existing DH networks
	Building ownership:
	
	• Public building
	• Commercial building
	• Domestic building:
	  o Social housing
	  o Private rented
	  o Owner-occupied
		Existing heating types
		
		Indices of multiple deprivation (such as health issues and fuel poverty)
		
		Eligibility for ECO (CSCO areas)

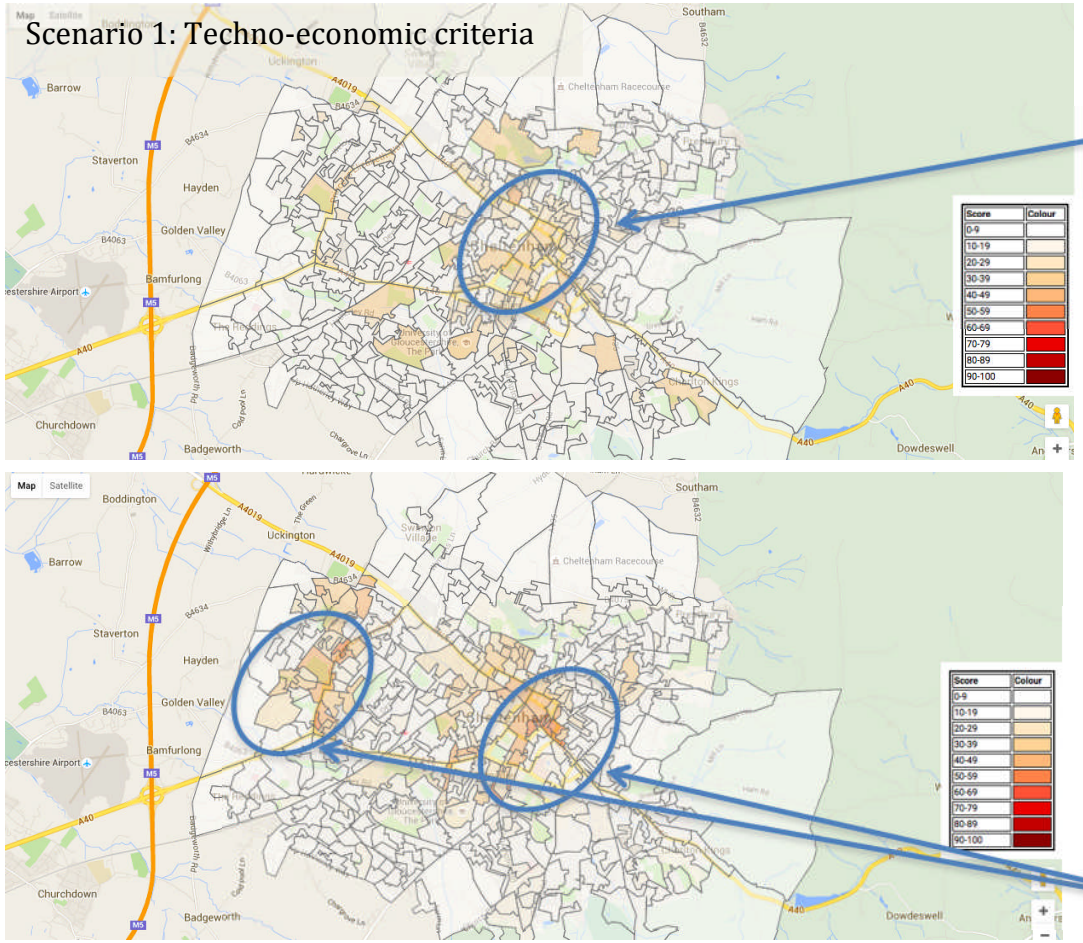
Going beyond techno-economic data to include this broader set of indicators encourages local authorities to adjust their decision making process for their specific local context and priorities. It also reduces the risks perceived by decision makers by explicitly prioritising risk mitigation factors within the prioritisation process.

The tool design aims to encourage stakeholder dialogue. The scoring system, with the ability to add weighting and switch indicators on and off, encourages exploration of different priorities. It also makes the strategic objectives for projects more explicit within conversations with local stakeholders. The next section gives an example of two different weightings used within the tool (one using only techno-economic indicators, and one including social indicators). Comparison of the two maps highlights where there are opportunities to develop schemes that might support fuel poverty alleviation versus where there opportunities for schemes that prioritise achieving maximum commercial rates of return.

6.3.3. Part 2: Application of the Leeds Heat Planning Tool

Figure 10 presents an application of the Leeds Heat Planning Tool to two example weighting scenarios in the town of Cheltenham (chosen as an example of a medium sized town that currently has no DH). By setting the tool in scenario 1 to consider only techno-economic criteria it identifies areas in the town that offer the highest potential for schemes to offer a commercial rate of return (the scoring of an area is

indicated by its colour shade – the darker an area is shaded, the higher score it has achieved under the selected weighting). When social characteristics are included within the weightings, an area that previously seemed to be an isolated opportunity becomes more interesting in terms of developing a project with fuel poverty alleviation objectives. The capacity to change the weightings used in the mapping make it possible for decision makers to consider and discuss the impact of different priorities on their approach to DH development.



Scenario 1 gives weighting to areas with large heat demand users and high household density – criteria that would be prioritised to identify the sites most likely to offer a commercial rate of return.

The area southeast of the town-centre appears to be a potential area for further exploration (including a hospital, swimming pool and commercial shopping centres)

Scenario 2 includes indicators of fuel poverty, the index of multiple deprivation, and eligibility for a form of government funding within the weighting calculation for each area.

Including social criteria highlights the potential of a site to the west of the town centre, which includes a school and dense social-housing, in addition to the original area of interest. It also highlights an opportunity to incorporate fuel poverty alleviation objectives into the area identified in scenario 1.

Figure 10: Two heat maps of Cheltenham, produced using the Leeds Heat Planning Tool representing two distinct decision crit eria scenarios: 1) Considering only techno-economic criteria, 2) including social criteria (Specific weightings used for each scenario are included in Appendix F).

6.3.4. Part 2: The tool in practice and areas for further work

The Leeds Heat Planning Tool represents one example of how heat mapping tool design can be adjusted to offer greater support to the early stages of DH development. However, there are several limitations of the tool presented here:

- Lack of data availability was a significant challenge for representing key indicators within the tool, as it is with all heat mapping exercises. This is particularly acute for the heat density proxy used in this tool, where users must manually enter the locations of large, non-domestic heat demand users. Data on potential sources of recoverable heat is also significantly lacking across the UK. This lack of appropriate data limits the potential impact of the tool
- The tool is only intended to offer an indication of potential, and does not attempt to indicate economic or technical viability. It should therefore be applied carefully to stimulate and inform discussion at the early stages of development only.
- Despite modifications to enable heat mapping tools to better support strategic niche management, it still relies on openness of users to embed it into the decision making process through dialogue internally within the local authority and externally with local stakeholders.

At this stage, the tool has not been formally tested with stakeholders, although there are currently users from 44 distinct organisations registered to use it and informal feedback has been received. 40% of registered users are from local authorities. In addition, another 38% of registered users are from private energy companies and consultancies (the remaining 22% of users were from universities). The range of actor types registered for the tools suggests that it is of wider relevance to those other than local authorities. It would be useful to explore the practical application of the tool in further work. Do the features of the tool support DH development as they were intended? Can this form of tool build the foundations for the application of more detailed heat mapping tools to support empowering processes for achieving a strategic approach to DH? A suggestion for further work would be to explore these questions in more detail. However, due to

time constraints for conducting this research, it has not been possible to address these questions within this thesis.

6.4. Chapter conclusions

Part 1 of this chapter explored how local authority actors within the case study used heat map tools to support niche processes for DH development. It showed that heat mapping tools were sometimes used by actors to support niche nurturing processes by informing identification of where relationships with key stakeholders need to be developed, providing a framework for developing understanding and skills of local authority actors new to DH development, and providing a visual evidence base that can be used for demonstrating the potential of DH in a given area. Heat mapping tools also had the potential to support niche empowering processes when embedded with long-term resources, knowledge, and niche actor capacities.

However, the use of heat mapping tools for these purposes was not consistent. The tools needed to be adaptable for the context and the actors who are using them. The study recommended that a tool's functionality should be flexible enough to enable niche actors to incorporate their own visions and objectives, rather than visions be imposed via the tool design. It also recommended that heat mapping tools would be better utilised at the early stages of DH development if they were easy to learn to use without need for investment of significant resource on the part of niche actors. Early utilisation of the tools could enable them to gain legitimacy with niche actors by opening up dialogue between actors and facilitating prioritisation of opportunities, rather than endorsing one particular course of action.

Investing time and resource into embedding use of heat mapping tools into decision making at the early stages of niche creation paves the way for their application later down the line in creating wider system change. An established and embedded heat mapping tool can support diffusion of an innovation from niches into the wider regime by informing strategic planning for DH development, providing evidence of the potential extent and value of the innovation. However,

delivery of such local strategic energy plans requires accompanying local powers and capacities that are unlikely to be accessible to niche actors without the support of actors from outside of the niche such as national government policy makers. Building up the agency of local actors to drive a transition to DH therefore relies on support from other actors who are likely to be embedded within the institutions and practices of the incumbent regime. This challenge of gaining support from regime-embedded actors is explored in more detail in chapter 8.

Responding to the recommendations made in part 1, part 2 of the chapter explored the practical implications of implementing these recommendations by developingan example heat map tool that might better support the early stage of DH development. The experience of developing a tool in this work shows that these recommendations can be difficult to achieve in practice. The established methods, technical capacity, and data availability were not necessarily suited to decision making around the innovation, and instead are geared around the incumbent regime requirements and practices. Resource limitations and actor capacities also made them hard to put into practice.

The next chapter explores the second potential governing measure identified within the pilot study presented in chapter 5 – the role of intermediary activities. Taking a similar approach as within chapter 6, the analysis presented within the next chapter seeks to understand how intermediary activities support niche nurturing and empowering processes within the case study.

7. The role of intermediary activities as a measure for governing a transition to district heating

7.1. Introduction

This chapter explores the role of intermediary activities as a measure that could contribute to governing a transition to district heating (DH). The pilot study presented in chapter 5 highlighted the importance of local actor relationships and networks for enabling successful development of DH projects. Projects often relied upon trust between actors and the social capital of the actors leading development (Hawkey et al., 2013). The case study also showed the central role of local authority actors as a coordinator and leader of activities around DH at the local level (e.g. the housing association actor and energy company actors interviewed within chapter 5 both highlighted the need for leadership from local authorities before they would commit to being involved in certain DH projects). Furthermore, knowledge and skills related to DH were often felt to be lacking amongst local actors. The socio-technical transitions literature has begun to explore the importance of actors that facilitate relationships between key actors and enable sharing and pooling of knowledge. These actors are called intermediaries and their activities form the focus of this chapter.

The role of intermediary activities for governing socio-technical transitions is still an under-researched area.

7.1.1. Research questions

Taking a similar approach to chapter 6, within this chapter the DH development process continues to be conceptualised as a process of niche creation and development. The overarching research question of the thesis is again narrowed within this chapter to consider specifically governing of niche nurturing and empowering processes as a means for contributing to the governance of a transition to DH (Smith and Raven, 2012). The analysis does not consider shielding

processes since niche actors have limited control over these types of governing measures within the case study. The research questions within this chapter are therefore:

1) How do intermediaries support nurturing and empowering processes within the case study?
2) What lessons can be drawn from analysis of this aspect of the case study for governing a transition to DH?

The chapter uses data from phase 2 of data collection, where a decision theatre research method was used to collect empirical evidence from a range of local stakeholders involved in establishing new DH projects within the case study. This method, carried out in a group workshop format, enables understanding of the interactions between stakeholders throughout the stages of the DH development process.

The chapter is structured as follows: Section 7.2 presents the theoretical approach used to conceptualise the case study and research questions. The analytical approach used for considering the empirical data is set out and justified in section 7.3. In section 7.4, the method of data collection is outlined, where a decision theatre workshop for a range of local stakeholders involved in DH development was used. In section 7.5, the results of the analysis are presented and discussed, and section 7.6 draws specific lessons from the analysis on the role of intermediaries in delivering niche empowering processes. Finally, in section 7.7, conclusions from the chapter are summarised.

7.2. Theoretical approach

Intermediaries are actors and institutions that perform connecting and mediating functions. Intermediaries are recognized as playing an important enabling role in the delivery of niche nurturing processes (Kivimaa, 2014). Their activities enable exchange of knowledge, and development of skills and standards to support the process of innovation (Geels and Deuten, 2006; Kivimaa, 2014). The literature on the role of intermediaries in strategic niche management offers a conceptualisation of how socio-technical transitions might be facilitated and supported by

intermediaries. However, there are still relatively few empirical studies that explore their contributions to transitions. (Existing empirical studies are reviewed in the next section).

Intermediaries are actors or organisations that range from public bodies, to trade associations, non-governmental organisations (NGOs), or consultants (Küçüksayraç et al., 2015; Lovell, 2007). Their work spans individual niches, networks and learning boundaries and they can undertake work at multiple geographical levels; using their expertise to enable delivery of innovations by mediating between different interests, making connections, enabling relationships, or aggregating and sharing learning between similar niches (Geels and Deuten, 2006; Kivimaa, 2014; Hargreaves et al., 2013).

7.2.1. The role of intermediaries in delivering niche processes

Studies to date have focused on demonstrating the role that intermediaries play in delivering niche nurturing processes and sharing of knowledge between local niches (Hargreaves et al., 2013; Hamann and April, 2013; Hodson et al., 2013; Kivimaa, 2014). In a study of organisations in Cape Town, South Africa, Hamann and April (2013) illustrate how intermediaries play a role in establishing a shared vision between actors for a sustainable innovation, to enable collaboration between diverse communities. In two studies, Hodson and Marvin (2010) and Hodson et al. (2013) explore the influence of 'energy' intermediaries in enabling cities to play a role in transitions by building local actors' capacities and capabilities to act, as well as establishing a shared understanding of an innovation between multiple local actors. Kivimaa (2014) make a first review of the intermediaries literature within socio-technical transitions, and highlight the multiple roles that intermediaries can play, particularly in nurturing niche processes that enable actors to develop and learn about an innovation. However, several empirical studies highlight common challenges faced by intermediaries due to their own limited resources and capabilities, as well as a lack of devolved powers and ability to reconfigure governance systems for local level actions (Hawkey et al., 2013; Hodson et al., 2013; Küçüksayraç et al., 2015; Thakore et al., 2013).

The role of intermediaries in facilitating niche empowering processes

Although most of the existing intermediaries literature focuses on nurturing processes taking place internally within niches, studies have also begun to recognise intermediaries as having a role beyond nurturing, in supporting the niche empowering processes. Geels and Deuten (2006) suggest that the formation of a 'global' niche is an important part of this process, enabling an innovation to diffuse and to embed into the regime. A global niche is the aggregation of experiences and learning from a number of 'local' niches to form a collective knowledge about the innovation. The collective strength of this global niche has the potential to establish a space within the incumbent socio-technical regime where an innovation can continue to diffuse (see chapter 3). Geels and Deuten highlight a role for intermediaries in enabling knowledge sharing and aggregation between the local niches. Intermediaries also have the ability to form communication channels between regime actors and local niche actors to both share experiences and articulate the values of niche innovations, as well as to feedback perspectives from the regime into niches (Kivimaa, 2014; Hargreaves et al., 2013; Hodson and Marvin, 2010).

Activities for driving a transition through facilitating niche empowering processes are not currently considered in depth within the empirical literature on intermediaries. Instead, studies mainly focus on how intermediaries nurture innovations within niche spaces. Initial work on intermediaries facilitating systemic transition has considered the role of intermediaries in cities. Hodson and Marvin (2010) demonstrate how world cities, such as London, New York, and Tokyo, are forming and acting on their own urban transition visions, instead of focusing on diffusion of innovations to a national scale (as is sometimes assumed by much of the transitions literature). This work suggests that the role of geographical scale and actors' conception of the socio-technical system is important for understanding the role of intermediaries in this process. Hodson and Marvin (2013) also highlight the influence of context and agency of intermediary actors over their ability to influence systemic socio-technical changes. They present a conceptual framework to explore the modes of intermediaries' characteristics (outlined in section 2.3), which is drawn on during the analysis in this chapter.

7.3. Analytical approach

The analysis in this chapter is conducted using an analytical framework defined by Kivimaa (2014), to identify where intermediary activities are supporting niche processes within the case study. The framework is categorised by different roles that intermediaries can take to support niche nurturing processes. Under these categories, practical intermediary activities are used, identified by Kivimaa (2014) from a number of empirical examples. These are used as guidance for identifying examples of intermediaries within the DH development process in the case study. These are summarised in Table 7.

Table 7: Analytical framework categorising types of intermediary activities into the four roles that intermediaries play in sustainable transitions ([1]Kivimaa (2014) and [2]Hargreaves et al (2013))

Articulation of values and visions	Building of social networks	Exchange of knowledge and supporting learning processes
• Strategy development • Demonstration of technology benefits • Acceleration of the application and commercialisation of new technologies	• Aligning interests • Creation and facilitation of new networks for both learning & project delivery • Finding funding sources to support activities.	• Knowledge gathering, processing & combination • Communication and dissemination of knowledge • Advice and support

In addition, the role of intermediaries in supporting empowering processes is considered. This role for intermediaries was initially recognised by Hargreaves et al. (2013)) as "brokering and coordinating partnerships beyond the niche. Table 8 details practical examples of intermediary activities, as identified by Hargreaves et al. (2013), that support empowering processes for widespread uptake of the technology and a transition to a supportive regime.

Table 8: Intermediary activities observed by Hargreaves et al. (2013) which support brokering and coordinating partnerships beyond the niche.

Brokering and coordinating partnerships beyond the niche[2]
• Accreditation and setting of standards • Consultation on policies • Policy communication and implementation

Building upon the findings of this initial analysis, a second framework is used to explore the characteristics of actors delivering empowering processes within the case study (Figure 11). The framework was developed by Hodson et al. (2013) to highlight the different modes of urban energy intermediaries. It enables consideration of "whose priorities are being pursued by energy intermediaries and how this is translated into programmes and projects" (p.1420, Hodson et al., 2013). Through exploring the two dimensions of the framework the work begins to consider if there are critical characteristics of intermediaries for contributing to empowering processes. The two dimensions of the framework are:

(1) The **scale and depth** at which intermediaries and their functions are embedded into institutional practice - Intermediary activities can be delivered as a stand-alone response, or they can be delivered in a systemic way, for example through embedding within the long-term functioning of existing organisations. They can be delivered at the local niche level, or across multiple niches. Hodson et al. (2013) note that intermediaries that deliver a longer term and sustained approach are more able to bridge and facilitate between multiple actors. Balancing this, local, stand-alone responses are able to adapt to specific circumstances and opportunities to enable successful local delivery of an innovation.

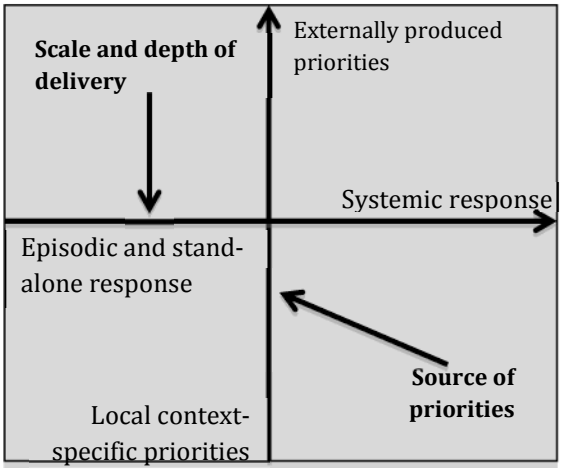


Figure 11: Modes of urban energy intermediation conceptualised by (Hodson et al., 2013). The x-axis shows the scale and depth of delivery of intermediary activities, and the y-axis shows the scale at which the priorities for intermediary activities are defined.

(2) The **source of priorities** driving intermediaries' activities – Intermediary priorities could be driven by local priorities, through to a top-down national policy objective. The roots of an intermediary's priorities influence their ability to effectively communicate and empathise with diverse actors across the regime and niche spaces. For example, an intermediary driven by the interests of regime-embedded actors may be constrained in their activities and be unable to pose

radical disruption to incumbent regime practices. On the other hand, an intermediary driven by niche-based actors' priorities may be more able to challenge regime practices.

7.4. Empirical data: Use of a decision theatre methodology

Data was collected for this chapter through an adaptation of a decision theatre; a method originally developed by Arizona State University as a way of using complex data visualisation, modelling and simulation to facilitate collaborative decision making between a group of relevant stakeholders in a complex group decision process (Walsh et al., 2013; Bale et al., 2014; White et al., 2010).

The method was originally focused on increasing the impact of quantitative modelling and data analysis within complex decision making processes, and it made use of high-speed servers with multiple screens in a bespoke room as means for displaying data to participants (Walsh et al., 2013). The method in this form enabled collection of rich and detailed data both about the role of evidence and data within a decision process, and also about the interactions and relationships between stakeholders during the process of decision making. The number of stakeholders participating within previous decision theatres, and the set up of the process, has varied according to the issue in focus and the objectives of the research project. For example, White et al. (2010) held several sessions, splitting participants by roles into 'policy makers', 'data analysts', etc. This approach allowed them to explore different dimensions of the decision making process according to the type of stakeholder.

For the purposes of this research, the decision theatre process and objectives were adapted to contribute data relevant to the chapter's research questions about the role that intermediaries play in supporting niche processes for DH. The decision making process surrounding DH development combines techno-economic, quantitative factors, with non-quantifiable factors such as the conditions of the local economy, investors' appetite for risk, and perceptions of the technology held by key institutions such as the local authority, housing associations or the local university. Therefore, the decision theatre method was adapted to focus upon the

interactions and relationships between different stakeholders during key decisions throughout the development process. This enabled analysis of where actors were playing an intermediary role in the development process.

A range of 8 stakeholders involved in a range of professional capacities in local-level activities for establishing new DH networks across different areas in Great Britain participated in the daylong decision theatre workshop held in Newcastle, UK during October 2014 (10 stakeholders were originally invited only 8 were able to attend on the day). Stakeholder selection was focused on local-level actors to explore the experiences and learning processes of actors during DH delivery, rather than wider policy processes. The workshop was attended by 5 local authority sustainability / energy officers, a university estates energy manager, a representative of a community energy group and a local enterprise partnership representative. None of the participants had successfully completed a DH project but all were actively involved at one of the stages. The workshop was organised so that stakeholders with different kinds of organisational experience and knowledge were grouped together.

The number of stakeholders participating in the workshop was kept small to enable the decision theatre to collect data at the level of detail required to usefully inform the research process. Participants were purposefully chosen from a range of different geographical areas and contexts, to capture if there were different perspectives between participants. This small number of participants meant that the findings represent a case study of a potential project development process, rather than a representative sample of all project development in Great Britain. However, this case study approach enabled the detail of project development to be explored in sufficient detail to highlight where intermediaries can play a role in supporting niche processes and consider where there are potential gaps in provision or opportunities to improve support.

While conversations were limited to participants in the workshop, conversations were contextualised within a wider policy framework by ensuring any comments and questions needing to be addressed by national policy stakeholders such as government ministers were captured via sticky notes and pinned to their poster

image. This approach allowed the participants to discuss their interactions with actors not represented in the room, and to identify issues and concerns that needed to be addressed at different scales such as through government policy measures.

Discussions were facilitated and activities designed to steer conversations about the development process towards the relationships and interactions between various stakeholders rather than on solely technical or financial questions about the viability of a project. Using a fictionalised scenario was important because this enabled participants to draw out issues and concerns, based on their own professional experiences but in ways that did not compromise other professional relationships.

In the scenario presented to the workshop participants, three key 'stages' of a fictional DH development process were presented; namely pre-feasibility, feasibility, and delivery stages, as detailed in Figure 12. The participants were set the task of discussing how they would develop the case study example from the pre-feasibility stage through to delivery. At pre-feasibility stage, participants were presented with an example of an area-wide heat map that indicated heat demand density including a number of specific large heat demand users that might be able to act as key anchor loads for a network, as well as existing CHP plants and other potential heat sources. At the feasibility stage, participants were presented with information about a specific priority project that had been selected for further exploration with a feasibility study. Finally, at the delivery stage, the groups were informed that the given project was technically and financially viable for delivery, given the involvement of key anchor loads and heat supply sources. Participant discussions were facilitated around the key points listed in Figure 12 to explore different actors' objectives and challenges at different stages of the process, including:

- When and where actors sought advice and resources to support project development
- Actors' perceptions of risks,
- Differences in objectives between stakeholders,

- How available information was used to inform decision making,
- The process of stakeholder engagement and relationship building

Mixing research participants provoked vibrant decision-making situations because the different perspectives represented within the group encouraged each participant to vocalise, explain and defend their reasons for deciding to act in a particular way[12]. Feedback from the participants suggested that this approach proved valuable for the research participants themselves, allowing them to share and learn from each other and to reflect on their own work as they progress through the stages of the workshop.

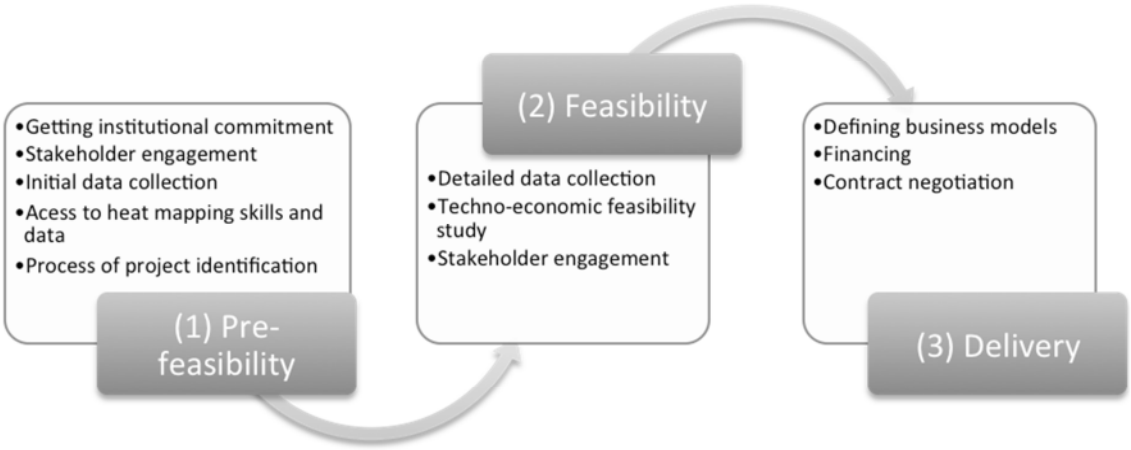


Figure 12: Outline of the three stages of the DH development process considered within the decision theatre workshop. Example activities from each stage are given. Although this diagram suggests a linear process, iterations between each of the activities often take place over time as contexts and stakeholders change.

Having secured agreement in advance, group conversations and narratives were audio recorded for later analysis. Session conveners queried participant comments during each of the three stages in an effort to reveal some of the underlying decision-making rationales. In this way it was possible to gain an insight into the interests and focus of each participant and align these with their experiences of

[12] The present author was supported in delivery of this workshop by a team of 5 researchers connected with the iBUILD research project (https://research.ncl.ac.uk/ibuild/). The candidate defined the overall structure of the workshop. Tasks for workshop organisation and detailed activity design were shared out between the various group members. The candidate was also one of three facilitators who led group discussions. All work beyond delivery of the workshop, including data transcription and analysis, was carried out by the candidate alone.

working in particular kinds of economic, political, and policy contexts. Data was transcribed and analysed for the themes and activities outlined within the analytical framework, defined in Tables 7 and 8, to identify how and where intermediary activities were taking place throughout the development process stages.

7.5. Results and discussion

7.5.1. Evolution of intermediary roles throughout the DH development process

Table 9 presents the results of the data analysis using Kivimaa's intermediary framework (Kivimaa, 2014), set out in section 7.3, to identify the intermediary activities supporting progressions through the stages of the DH delivery process. Alongside this, challenges encountered by practitioners, or recognised gaps in the existing intermediary provision within the case study are summarised. Most of the actors within the decision theatre were at stages (1) and (2) of the delivery process, establishing conditions for successful development of an initial project.

Table 9: Types of intermediary activities undertaken at each stage of the DH development process, categorised into the three dimensions of Kivimaa's intermediary framework (Kivimaa, 2014).

Intermediary role	Development stage	Activity observed in the case study	Challenges or gaps in intermediary provision?
Articulation of values and visions	**(1) Pre-feasibility**	**Increasing local awareness of DH opportunities (internally and externally)**: In the context of very little existing DH, it is rare that local stakeholders had experience of the technology at the start of a project. Local authority intermediary activities to raise awareness of the technology's potential could be observed both internally within a local authority, and externally, focused on introducing key decision makers to the technology. For example, before initial heat mapping could take place internal local authority stakeholders needed to be persuaded that this was a valid use of scarce local authority staff and budget resource and to make the case that this was of sufficient priority to justify investment.	**Lack of local authority resource** to undertake these early intermediary activities and establish a common understanding of the value of DH was a key challenge in progressing through the development stages. One solution was to establish activities at the regional authority level, such as the local enterprise partnership. The **pooling of resource** at this stage enabled work to be undertaken on behalf of local authorities that would not have been able to take place otherwise.
	(2) Feasibility	**Creation of an evidence base to demonstrate viability:** Local and regional authorities gathered detailed data to feed into feasibility studies; obtained funding for a feasibility study to be carried out by an expert consultant (funding was primarily obtained through a grant from national government, or alternatively by direct funding from the local or regional authority).	
	(3) Delivery	n/a	

Intermediary role	Development stage	Activity observed in the case study	Challenges or gaps in intermediary provision?
Building of social networks	**(1) Pre-feasibility**	**Aligning interests and establishing cooperation between key-stakeholders (internally and externally to a local authority)**: Local authorities and regional local enterprise partnerships worked to create partnerships between potential external partners by holding consultation meetings, and shaping project design to meet the varying objectives of stakeholders.	There was still some frustration amongst local authorities that opportunities were being missed through **lack of established communication channels**: *"There should be a duty to consult with neighbouring organisations. […] In [our city] we've got a prison, a hospital, and so on, who will be thinking about [their sustainability statement for the treasury standards]. So thinking about plant placement and plant investment, which all could be part of the jigsaw of a future district heating scheme. But there is no duty apart from to themselves. They don't need planning permission for this sort of change, so the local authority wouldn't necessarily know...it would just be really simple."* (Local Authority)
	(2) Feasibility		
	(3) Delivery	**Acting as a catalyst for new schemes and expansion:** There were two approaches used for this purpose. Local authorities could use planning powers to lever in private delivery of DH schemes in new-build developments. Alternatively, the local public sector estate could be used to offer an anchor load of long-term heat demand to increase certainty around the long-term business case for a scheme.	**Perceived lack of powers to establish strong planning policy**: Although local authorities well understood the potential of planning policies, their use was not always considered successful or viable in the absence of national policy measures, because of competition for attracting developments to their area.
		Local authority-led development to enable access to lower-cost finance: Local authorities considered using their own borrowing power, through **public sector-only access to low-interest loans** to enable development of strategic schemes that might not otherwise have been developed due to too low returns on investment for private investors.	**Local authority aversion to taking on greater levels of debt and risk –** DH was perceived as a risky investment for local authorities. Some local authorities also had a limit to the amount of debt that it could take on at any one time. Deciding to invest in a DH network would mean that investment would have to be curtailed in another area.

Intermediary role	Development stage	Activity observed in the case study	Challenges or gaps in intermediary provision?
Exchange of knowledge and supporting learning processes	(1) Pre-feasibility	**Creation of an evidence base to demonstrate viability:** Since local authorities lacked key skills for carrying out opportunity assessments, they would commission a consultant to undertake an initial study of potential opportunities in their area.	HNDU played an important role supporting projects through the development process, as well as connecting and sharing information between key contacts at local authorities. However, participants identified a gap in opportunities for knowledge sharing between non-local authority peer groups, such as university or hospital finance directors, as well as specific officers within local authorities such as planning officers or local politicians.
	(2) Feasibility	**Sharing of case studies to overcome high perceptions of risk:** Despite the involvement of expert consultants and techno-economic analysis of projects, the appetite to take risks to enable a projects' success was often felt to be low. Case studies were seen as an important tool for increasing confidence in DH. Participants talked of the "responsibility" of successful projects to share more details with others.	
	(3) Delivery	**Use of technical, financial and legal consultants:** to inform financing decisions, business models and technical specifications for construction, operation and maintenance.	The involvement of consultants was important for bringing in more expertise and experience to the process, but actors expressed a worry that some consultants were bidding for work that they did not have expertise to do. HNDU was used to sense-check reports in some of these situations.

This analysis of the DH development process shows the important role that intermediaries can play in delivering niche nurturing processes. The intermediary roles evolve as projects develop to fulfil new functions and serve different needs. Activities at the beginning of the process served to convince key actors of the value of DH and potential benefits that could be realised with use of the technology. As the project developed to the later stages of feasibility and delivery this intermediary role became less important and activities shifted to focus on building of social networks and exchange of knowledge between actors.

7.5.2. The multiple scales of intermediary activities

Intermediary activities took place at multiple scales to offer distinct benefits. In particular, analysis of the decision theatre data again highlighted the central role of local authorities in supporting DH niche processes, either undertaking intermediary activities themselves or being supported by the intermediary activities of others. However, activities also took place across other geographical scales: regionally (several local authorities working together through a local enterprise partnership or regional authority); and nationally (via institutions such as trade associations, community group networks, or government programmes).

However, the role of the regional and national authorities as a lead in delivery reduced at the later stages of development and their role served more as a source of advice to the local authorities, who necessarily took a leading role for specific stakeholder negotiation, contract agreements and financing decisions:

> "A*s it gets into the more detailed stages, we don't know their local authorities in the end. […] They know the local actors that are going to have an influence on the network, more than we ever could."* (LEP)

Figure 13 shows examples of the range of local stakeholders involved with DH development and the connections where local, regional and national actors were taking on an intermediary role.

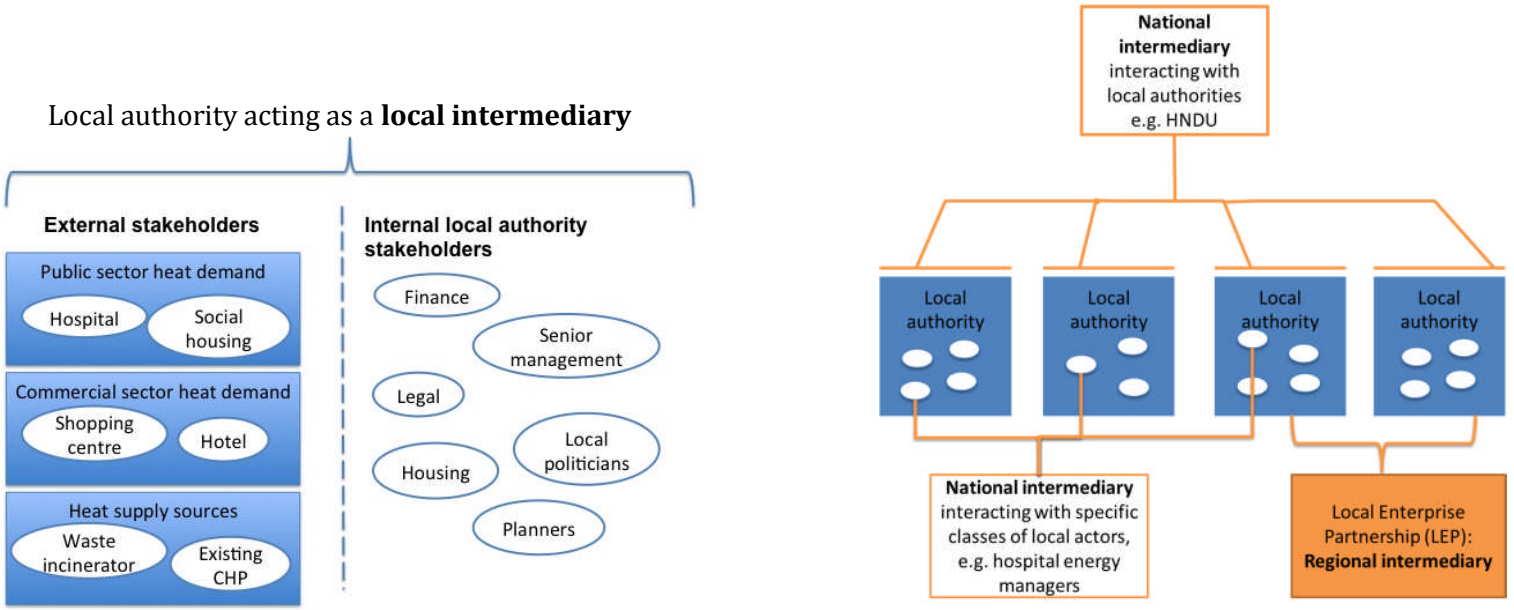


Figure 13: Illustration of the local, regional and national intermediary relationships where engagement and networks currently exist for enabling DH development in the case study. There are two types of national intermediaries represented: (1) that works with local authorities and (2) that works with other specific types of actors such as hospital or university energy managers.

At the **local level**, the local authority sustainability or energy team played an intermediary role by persuading local stakeholders of the value of DH, and building the social networks required to deliver projects. These activities were directed both externally, facilitating cooperation between local, public and private sector stakeholders, but also internally to develop local authority capacity and get corporate buy in from across the local authority. As new actors in the energy system, these intermediary activities internally within local authorities were crucial to creating the multi-skilled team of planners, mapping specialists, lawyers, finance specialists and energy managers needed to facilitate strategic DH development. Given this finding, it would have been interesting to have a range of local authority officers involved in the decision theatre workshop to enable data collection and perspectives not just from energy and sustainability officers but also planning, economic development, roads, housing, etc.

Beyond the local authority, other actors involved in intermediary activities at the local level were community energy groups, who explored opportunities to develop community owned schemes. Private sector DH companies also played an intermediary role, sharing expertise and experience from previous schemes, and offering to deliver and operate commercially attractive schemes.

At the **regional level**, local enterprise partnerships were sometimes undertaking intermediary activities as well. Their regional scale, joining multiple neighbouring local authorities, enabled employment of a specialist staff member for DH that would not have been possible for individual authorities acting alone. This scale of working also facilitated greater sharing and cooperation between the neighbouring local authorities working on similar challenges.

National level actors undertook intermediary activities between local actors, although none provided comprehensive coverage, or had enough capacity to meet the demands of all of the local actors. Key successes were HNDU, primarily acting as a source of funding to enable English and Welsh local authorities or regional local enterprise partnerships to buy in consultancy expertise, and also as a source

of information sharing between local projects. The Core Cities group[13], the Vanguards Network[14] and the trade associations (Association of Decentralized Energy (ADE) and the UK District Energy Association (UKDEA)) were also cited as valuable sources of information and best practice sharing.

7.5.3. The role of intermediaries in supporting empowering processes

The results of the analysis using Kivimaa's intermediary framework (Kivimaa 2014) highlighted the multiple scales and evolving role of intermediaries throughout the DH delivery process. However, giving considering to Smith and Raven's niche processes, the activities identified with this framework primarily support niche nurturing processes.

This section presents an analysis of where intermediary activities were contributing to niche empowering processes for DH. Based upon the results of this analysis, the framework of intermediary typologies proposed by Hodson & Marvin (2013) is used to discuss where these activities sit within the framework's typologies, and how these might need to be adjusted to better support DH niche empowering processes. Specifically, it considers the role of intermediaries for facilitating the formation of a global DH niche (Geels and Deuten, 2006) based upon the experiences of local niches across the case study. Finally it discusses general lessons for understanding the role of intermediaries in niche empowering processes.

[13]The Core Cities is a network formed to represent the local authorities of England's eight largest city economies outside London along with Glasgow and Cardiff, aiming to enable each city to enhance their economic performance and attractiveness as places to live, work, visit and do business.

[14] The Vanguards Network was set up by the University of Edinburgh as a forum to discuss detailed aspects of DH development for local authorities in the UK at a more advanced stage of the development process.

Table 10: Results of the data analysis indicating intermediary activities that support niche empowering processes, as well as identified challenges and gaps in provision.

Intermediary activity supporting niche empowering processes	Challenges in delivering this activity
Creating a supportive local policy framework for strategic development of DH: Local authorities sought to play a strategic coordination role for district heating development; highlighting opportunities for interconnection or expansion of existing networks, and using their local planning powers to require consideration of DH in new developments and refurbishments where appropriate. They saw this type of intermediary action as encouraging and supporting private sector-led DH development, whilst also demonstrating the technology's viability locally. Some local authorities also undertook activities at local strategic level, mentioning DH explicitly in their climate change action plans or fuel poverty strategies.	**Lack of resources** was a key issue for local authorities undertaking work on DH. Development of low carbon energy is not a formal responsibility for local authorities within Great Britain and had to be done after legally mandated responsibilities had been fulfilled, such as social care provision or waste management. Some local authority actors lacked a clear steer on whether their local authority was willing to take on this new strategic role in local energy development: *"And part of that is because this is new. This is not core business. So perceived risk is greater."* (Local Authority).
Use of ownership models for strategic development: A local authority taking a lead role in developing and owning a DH network was seen as a way to establish a strategic influence over DH development, in the hope of levering greater benefits for the area (e.g. maintaining low heat costs for fuel poverty reduction, or generating income through scheme profits).	**Lack of precedent and experience** meant that there was a perception of risk associated with taking on full local authority ownership of a scheme. However, the option of a fully private scheme, or partnership with the private sector was also associated with caution. "*It's a way of diluting the risk and also bringing in expertise and funding. Because a local authority might identify it as a really wholesome thing to do, but they may not have done it before, and they don't have the funding for it. So I think to bring in an external partner - it would probably be an energy company that's got the skills and knowledge in both the design and delivery, and can get the funding. It's getting the balance right between the local authority and the private finance really. Because they can take over the nest."* (Local Authority)

The analysis presented in Table 10 indicates intermediary activities taking place within the case study were also seeking to play a role in supporting niche empowering processes. This seemed to be particularly important at the local level, but was supported by intermediary activities at other geographical levels.

However, delivery of these activities by local authorities faced challenges and represented a new role for the actors seeking to take them on. The following section uses the framework proposed by Hodson et al. (2013) (presented in section 7.3), to consider what these empirical findings suggest for the most appropriate mode of energy intermediation to support niche empowering processes for DH. Considering modes of energy intermediation for supporting niche empowering processes

Within this case study, the **scale and depth of intermediary activities** varied across geographical scales. At the local level, local authorities had the potential to play a crucial intermediary role for up-scaling delivery of DH at the local level. However, the scale and depth of their activities were not consistent. Local authorities were often seeking to deliver a systemic response by embedding their informal intermediary activities into local policy frameworks and governance (e.g. delivery of local heat strategies, planning policies and sometimes local authority-owned energy service companies). However, consensus was not yet established for the extent of local authority responsibility in this area, and governance structures in Scotland, England and Wales did not attribute formal responsibility for energy matters to local authorities. This led to variability in local authorities' level of political commitment to DH and the level of risk they were willing to take on to enable the development process. Combining this lack of an established approach (which would initially manifest as part of a global niche) with the challenges of internal capacity and lack of resources created significant barriers to many local authority actors playing a sustained intermediary role. For example, this was highlighted by a regional authority actor working to support local authorities on DH:

> "*The three local authorities that we are going to be doing additional energy masterplanning with, have all said that on their own they don't have the resources internally to project manage it, so we're sort of looking at how the [HNDU] funding can be utilised to bring in some project managers, and them actually sit within the local authority for two and a half days a week."* (LEP)

At the national level, intermediaries such as national government policy units and trade associations were able to deliver a more systemic response. The position of these actors embedded within the incumbent regime enabled levering of resource for niche actors and intermediaries, as well as use of shielding policy measures to support the innovation. However, these national level activities were not sufficient on their own to support empowering processes for DH innovations in local niches.

This analysis suggests that a systemic intermediary response is needed across the geographical scales to enable effective DH processes. As Hawkey et al. (2013) identified, the way that successful schemes have overcome these barriers to date is through a reliance on key individuals and social capital within the local authority. Pooling of resources at the regional level, such as in the cases of local enterprise partnerships, to enable consistent and expert support of the development process could be one way of moving beyond this reliance on individual social capital. In general, the crucial role that intermediaries provide in niche shielding, nurturing and empowering processes needs to be recognised and resourced to enable systemic delivery. This is particularly the case at the local delivery-level where capacity and resources to provide the required consistent, long-term intermediary functions are lacking.

To consider the **source of intermediary priorities**, the analysis again looks first at local level intermediaries embedded in local niches, and then considers national level intermediaries. At the local level, where local authorities had made commitments of resource and staff time in the absence of any national government mandate, intermediary priorities were driven by local priorities and objectives (although shaped by flows of resources from national government policy initiatives),

> "[*In our city],* w*e've got a Climate Change Strategy with senior level commitment. It's that obligation that is needed, because without the obligation I'd just carry on...I'm really busy, I've got less staff, I've got less resources. I don't need to change anything so why do it?"* (Local Authority)

This locally focused form of intermediary enabled sensitivity to local contexts, which was considered important for local niche processes. This differed from

national intermediary activities where energy policy priorities were driven from national government or large energy company agendas, which were strongly intertwined with the incumbent regime. However, this distinction from incumbent regime practices also created a perceived risk to local authorities delivering intermediary activities. For example, although some actors expressed a desire to retain local authority ownership to gain local benefits and to influence expansion and future development in the area, when it came to making a commitment it was felt that sharing risk with other actors, at least to some extent, was more appropriate for their capacity and ability to manage risk:

> "Facilitator: *If there is a predicted return of 12% over a scheme's lifetime, why would the local authority want the private sector to get involved?*
>
> […]
>
> Local authority: *Risk sharing. So the local authority's attitude to risk. So you want to share the risk and the rewards. Because the scale of the ultimate project could be massive. These things tend to start off with one scheme, but they can build over the years. So you want to share that risk and reward.*"

Currently, a local authority must shoulder the risk of investing their resources into the early project development stages, with the potential for no rewards at the end. A greater use of shielding policies, re-prioritisation of resources to the local level specifically for the purposes of energy planning and project development, as well as the establishment of best-practice for roles and responsibilities of local authorities could support local authorities to take on a more empowered role as local intermediaries and potentially enable them to risk a greater stake in ownership of projects themselves.

At the national level, a number of forms of intermediaries existed such as trade associations and a government policy unit (the Heat Network Delivery Unit (HNDU)). The nature and source of their priorities varied between intermediaries. For example, HNDU was ultimately driven by the objectives of national energy strategies rather than local authority priorities. Their main engagement with local authorities was to distribute resources such as advice and funding. In the case of the trade associations, they were driven by their members' priorities. This

membership included some local authorities, although private sector energy companies comprised their largest proportion of members. This made their activities less focused on the specific contexts and challenges of local authorities.

In general, there was a gap in intermediary provision for activities that linked up local authorities and regime-embedded actors. Local authority actors often articulated a need for regime-level changes or a greater need for shielding policies:

> *"A system that is easier to participate in and understand. A stable policy background and incentives."* (Local Authority)

> *"It's got to be consistent over the long term. The whole technology is reliant on the long term."* (Local Authority)

> "*The biggest thing that the government could do to unlock a lot of this is to come up with a direct financial incentive to build networks*." (Local Authority)

However, there was little evidence of an intermediary providing a coordinated narrative from local authority interests on the need for regime change to support DH development. Instead, individual local authorities fed their experiences through to regime actors such as the UK Government on an ad hoc basis.

Global niche processes

These findings add empirical support to the suggestions of Geels & Deuten (2006) about the importance of intermediaries for facilitating formation of a global niche as part of supporting empowering processes. Initial intermediary activities could be observed for establishing elements of a global niche, e.g. standards and practices for the delivery stage of the development process (stage 3). At the national level, the case study showed the early stages of forming a global niche. For example, a technical consultancy had produced DH technical guidelines (Wiltshire et al., 2014) and a trade association had founded an independent customer protection scheme to drive up standards and increase confidence in the technology (Association of Decentralised Energy, 2015). These activities were delivered by long-standing, established actors working at a national level, with the capacity to deliver a systemic approach to their work.

However, standardised practices were less well established for the earlier stages of DH development at the local level. For example, there was not yet consensus on the specific roles that local authorities needed to take on in the development process, either for area-wide strategic coordination or for leading on project development. Also, there was not an established understanding or acceptance of the technology across key local actor communities such as hospital energy managers or universities, whose networks spanned across multiple local niches. Although intermediaries for local niche actors existed for other purposes not related to DH, these intermediaries had not yet established activities beyond episodic responses to support DH development. The incumbent regime was not configured to support local actor delivery, and lacked actors who could play a long-term role supporting local niche empowering processes.

The formation of a global niche could potentially be helped by the creation of national or regional level intermediaries with a greater focus on niche priorities, particularly for the early stages of project development. Existence of this type of intermediary could also enable a better balance between representations of regime and niche priorities within niche-regime interactions. However, resources for such an intermediary would likely need to come, at least in part, from regime-embedded actors such as national government or a trade association. As suggested by Hodson and Marvin (2013), who considered the source of priorities of energy intermediaries in Manchester and London, it can be challenging for regime-embedded actors to designate resources to such a function without retaining at least some control over the intermediary priorities. A balance is needed between intermediary priorities set by regime actors and niche actors. Without niche-focused intermediary priorities, crucial aspects of niche contexts and practices are difficult to connect to build up local niche actor capacities or enable global niche formation. In practice, this balance between regime actor and niche actor priorities would likely be determined by the incumbent regime context and agency of actors involved. This issue is explored in Chapter 8.

7.6. Wider lessons on the role of intermediaries in supporting niche processes

This section now draws on the analysis to make a contribution to the socio-technical literature on intermediaries and niche empowering processes. The role of intermediaries within the case evolved as a niche establishes and nurturing processes progress. This section argues that this role also extends to encompass facilitation of niche empowering processes.

For intermediaries working at the local-level, their role might evolve from delivering niche nurturing processes such as stakeholder engagement and articulation of an innovation's value, to strategic coordination for widespread uptake. For intermediaries working at regional and national levels, they have the potential to share learning and knowledge across local niches to enable the establishment of global niche practices (Geels and Deuten, 2006). This analysis therefore adds empirical evidence to support Geels and Deuten's conceptualisation of local and global niches and the role of intermediaries for enabling its establishment.

The analysis suggests that empowering processes require the scale and depth of intermediary activities to take the form of a long-term systemic response, engaging at multiple scales. Empowering processes, such as establishing a global niche and influencing regime actors, require long-term access to resources, probably with multiple intermediaries providing different functions and connecting key communities. Where long-term resources existed in the case study (mainly held by national-level industry actors and national government), signs of a global niche formation could be observed. This suggests that national and regional-level intermediaries have a particularly important role to play in empowering processes. They enable the formation of a global niche for supporting both local niche processes as well as empowering processes for connecting beyond the niche.

The analysis also suggests that a balance is needed in the source of intermediary priorities across the range of intermediaries acting to support niche processes. Niche actor priorities reflect the specific challenges of local contexts but do not necessarily align with regime-actor concerns. This can restrict an intermediary's

access to resources and influence over regime trajectories. Regime-embedded actors' priorities reflect the concerns and tensions of the incumbent regime, potentially opening access to resources and a greater range of capacities such as use of policy levers to support their work. Their involvement also has the potential to add legitimacy to niche actor claims of the innovation's value, and opens the potential for steering of the regime trajectories closer towards a DH-friendly regime configuration. However, they do not necessarily connect with local concerns and challenges. Their embedded position within the incumbent regime also brings into question whether these actors are able to be an effective intermediary for the needs of a niche innovation that might need a radically different configuration of the regime to enable it diffuse. More research is needed to explore the role of regime-embedded actors in delivering empowering processes, and this theme is explored in chapter 8.

7.7. Chapter conclusions

This chapter has contributed to addressing thesis research questions 5 and 6, using a decision theatre research process to explore the role of intermediaries in delivering niche nurturing and empowering processes. The results illustrate the power of intermediaries for delivering these processes, showing that intermediaries play multiple roles throughout a transition. They can act internally within institutions to build understanding, buy-in and commitment for taking on a new role in supporting an innovation. They can increase understanding of an innovation amongst local niche actors to build a support network around the specific local context of the niche. They can also gather resources or provide specialist expertise to support inexperienced niche actors.

This work has addressed the gap in the intermediaries literature on their role in empowering processes. It has showed how the role of intermediaries could evolve to support empowering processes as a niche becomes more established. Embedding intermediaries systemically at regional or national scales is important for connecting up local niches and supporting establishment of a global niche. However, configuration of the incumbent regime can mean that intermediaries functioning at this scale are resourced and driven by priorities of regime-

embedded actors rather than focusing on niche priorities. The case explored here has shown gaps in provision and under-resourcing of intermediary activities at the local niche-level, preventing consistent support and effective dialogue across and between geographical scales.

The analysis suggests that intermediary activities need to balance the priorities and objectives of regime-embedded actors with those of niche actors, to enable development of local capacities as well as the formation of established approaches and standards for delivery. This brings with it questions about the agency of actors involved in the delivery of such an intermediary activity. Are national level actors willing and able to redirect resources to support intermediary activities that build capacity and autonomy at the local-level? Which actors have the freedom to deliver intermediary activities that support the realisation of radical visions for a DH transition? The next chapter explores these questions in more detail by considering the impact of incumbent regime resistance on the political narratives that actors use to support niche empowering processes within the case study.

8. Challenging incumbent regimes – niche actor agency in governing transitions

8.1. Introduction

The previous two chapters have highlighted how actors' agency influences the approaches that they can take to support niche processes within DH development. Chapter 6 showed how actors could make use of heat mapping tools to support niche nurturing and empowering processes, but this relied on access to resources and skills from regime-embedded actors. Similarly, Chapter 7 showed how intermediary activities can support niche nurturing and empowering processes across different geographical scales, particularly when delivered consistently over the long term. However, resources to deliver these activities were not distributed evenly across the actors delivering these functions in the case study. Instead, those actors who were part of established institutions within the incumbent regime held greater resources. This chapter seeks to explore this theme of actor agency in more detail by considering the influence of regime resistance over actors' approaches to driving a transition to DH. The work builds on the two relevant parts of the theoretical literature on actor agency in transitions, which are set out in the following two sections: Section 8.1.1 discusses the role of political narratives as a measure that actors can use to support niche empowering processes. Section 8.1.2 discusses the existing literature on the influence of regime resistance in transitions.

8.1.1. Political narratives as a measure to support niche empowering processes

This chapter focuses in more detail on the work by Smith and Raven (2012) that has been used as a basis of discussions throughout the thesis. In their work, and a preceding paper by Smith (2007), niche empowering processes are described as 'translating' innovations into the context of the socio-technical regime (Smith, 2007; Smith and Raven, 2012). They highlight actors' political narratives as a key

strategy for making this translation. For example, framing existing tensions within the incumbent regime is one way in which actors are able to argue for a radical change to the regime to enable the niche innovation to break in (Smith, 2007). Where tensions in the regime are perceived as high, this presents an opportunity for established niche innovations to diffuse or adapt to the regime (Smith, 2007). Smith and Raven (2012) argue that actors use political narratives either to argue that an innovation can 'fit and conform' with the incumbent regime, or that the regime must 'stretch and transform' to suit the niche innovation.

'Fit and conform' narratives argue for a transition where an innovation develops and adapts to a stage where it can compete within the selection environment of the incumbent regime. In this form of transition, shielding and nurturing processes play an important role for developing an innovation to enable it to diffuse without any radical change in the regime.

'Stretch and transform' narratives argue for a transition where the incumbent regime is transformed to a sufficient extent that it then becomes possible for an innovation to diffuse. The wider the gap between an innovation's requirements and the existing regime practices, the more challenging 'stretch and transform' transitions are to achieve (Smith and Raven, 2012).

In practice, transitions are likely to be messy, and full of competing narratives from different niche and regime actors (Smith and Raven, 2012). Translation activities are two-way and iterative, not just translating practices from the niche into the regime, but also resulting in adapting the practices of the niche according to translations from the regime (Smith, 2007). Translations of niche practices do not necessarily take all aspects of the original visions for an innovation. For example, Smith (2007) illustrates how the process of diffusing organic food supply resulted in only certain aspects of the original sustainable organic food niche being translated and adopted by the regime (i.e. large-scale organic production for distribution and supply by multi-national supermarkets rather than small-scale, local organic farming distributed by local shops). This left some niche actors unsatisfied with the loss of many of their original sustainability objectives and has

led to the invention of alternative niche spaces focusing on local and seasonal food (Smith, 2007).

Smith & Raven (2012) discuss the influence of actor agency when undertaking these types of activities to support niche empowering processes. Translation activities require niche actors to have access and command of "material and non-material resources, and collective action" (p.1031, Smith and Raven, 2012). They identify the importance of discursive strategies and narratives as a mechanism for actors to mobilise these resources, actor networks, and to influence the regime context. Intermediary actors play an important role because of their ability to draw on experiences and evidence from local niches and adapt their messages for key actors (Geels and Deuten, 2006). For 'fit and conform' empowering processes, embedded regime actors are a key audience, whereas for 'stretch and transform' empowering processes, a key audience are actors who are lobbying for institutional reform already. Smith and Raven (2012) highlight three types of characteristics they expect to see in narratives for empowering innovations:

1. Positive expectations about a future with widespread uptake of the innovation and niche practices
2. Arguments for specific institutional reforms that would favour the niche innovation
3. Criticisms of the incumbent regime, to highlight tensions where the innovation can provide a solution.

8.1.2. Considering regime resistance

Actors within a socio-technical regime reproduce its socio-cognitive rules and structures resulting in regime stability and lock-in to that particular regime configuration. The multi-level perspective conceptualises a transition to a new socio-technical regime as taking place as tensions in the incumbent regime create windows of opportunity for niche-based innovations to diffuse and destabilise the existing regime practices and establish new ones (Geels, 2004).

However, the socio-technical transitions literature has been criticised for not sufficiently considering the politics, power and agency of the niche actors seeking to drive a transition to a new regime (Berkhout et al., 2004; Smith et al., 2005;

Shove and Walker, 2007). Chapter 3 highlighted a key criticism of the multi-level perspective and its treatment of the socio-technical regime as "too descriptive and structural" (p.1492, Smith et al., 2005), neglecting to consider the influence it has on actors' choices at the niche level. For example, niche actors might need to cooperate with incumbent regime actors in order to access resources, and exert influence on regime dynamics.

In response to criticisms that this conceptualisation of the socio-technical transition process did not sufficiently consider power and politics (e.g Smith et al., 2005), Geels (2014) discusses how power and politics could be introduced more explicitly within the multi-level perspective by considering the strategies used by incumbent regime actors to resist regime change. Geels distinguishes between four ways that regime actors might resist a regime transition:

- **Use of instrumental forms of power:** Regime actors can use their resources such as facilities, staffing capacities, or relationships with media or decision makers to maintain a regime configuration to support their own interests. Regime actors usually have greater established resources to support regime reproduction and incremental adaptation than niche actors (Avelino and Rotmans, 2009);
- **Use of discursive strategies:** Regime actors can use their existing powers and resources to frame what and how is being discussed; seeking to shape what people care about (and what they do not think is important), and what people see as the 'best' solution to a problem.
- **Use of material strategies:** Regime actors can draw on their existing developed technical capabilities and financial resources to improve the technical sub-regime, making radical innovations seem less necessary.
- **Use of broader institutional powers:** The regime can have embedded political cultures, ideology and governance structures that grant privilege to embedded regime actors e.g. a liberalised market ideology, where 'picking technology-winners' by government is discouraged, grants privilege to actors with established capabilities, market positions and resources. (Geels, 2014)

Turning the traditional focus of socio-technical transition studies upside down, Turnheim and Geels (2012) focused on the process of regime destabilisation (the weakening reproduction of core elements of a regime). They argue that the causes of transitions are bi-directional, influenced both by what Smith and Raven (2012) termed niche empowering processes, and destabilisation of the incumbent regime. They use a case study of the decline of the UK coal industry since 1913 as an example of a completed destabilisation process, to identify key influences and phases of change in the process. They show how public opinion and discourse has an important role in influencing the cultural legitimacy of new innovations and incumbent industries. Policy change has an important role, although they suggest that gaining legitimacy for making radical policy changes requires the alignment of multiple processes such as reduction in political and / or public support for an incumbent industry, changes in economic context, and positive perceptions of the alternative solutions. They suggest that destabilisation of the fossil fuel industries would require "a greater public sense of urgency, stronger political will to introduce effective policies, more pressure from radical alternatives (wind, solar, biomass, etc.), and economic industrial problems" (p.47, Turnheim and Geels, 2012) .

8.1.3. Research questions

Given this theoretical background, the political narratives of actors working on DH development in the case study are used as an indicator of the type of transition approaches that actors are advocating more generally. This is then used as a focus for exploring actor agency and the influence of regime resistance. Analysis of case study data from phase 3 of data collection considers how actors' transition approaches are influenced by forms of regime resistance, using categories set out by Geels (2014) of forms of resistance used by regimes actors to resist fundamental system change. The research approach seeks to build understanding of the extent to which regime resistance and lack of agency restricted actors' actions around DH development, or whether they were able to make an intentional strategic choice about their approaches to influencing the direction of a transition to DH. The chapter uses empirical data made up of 29 qualitative interviews from a range of public and private, local, regional and national stakeholders, collected during phase 3 of data collection.

Specifically, the chapter addresses the following three research questions:

1) What types of transition approaches ('stretch and transform' or 'fit and conform') are indicated by actors' translation narratives used to support DH niche empowering processes?
2) How does resistance from the incumbent regime appear to shape actors' translation narratives?
3) What lessons can be drawn from this analysis for governing a transition to DH?

The rest of this chapter is structured as follows: section 8.2 outlines the analytical approach that is used to analyse the empirical data and address the research questions. Section 8.3 describes the methods used for qualitative data collection. The results and discussion of analysis are presented in section 8.4 and 8.5 respectively. Conclusions are presented in section 8.6.

8.2. Analytical approach

As in previous chapters, analysis of the data was conducted using a thematic analysis approach (Braun and Clarke, 2006), structured around a framework based upon the existing literatures on actor agency and regime resistance. For this chapter, two stages of analysis were used in order to address the chapter's research questions:

Stage 1

The first stage of analysis identified the translation narratives used by the various actors across the case study to consider the type of transition approach they were taking: 'fit and conform' or 'stretch and transform'. Actors were grouped by actor-type, to explore whether there were differences in approach across the public and private sectors or across actors working at different geographical scales.

Stage 2

The second stage of analysis then considered how resistance from the incumbent regime might influence these translation narratives identified in stage 1 of the analysis. Examples of regime resistance within the data were identified, using the

four types of regime resistance described by Geels (2014) as an initial framework to structure the thematic analysis:

- Use of instrumental forms of power;
- Use of discursive strategies;
- Use of material strategies;
- Use of broader institutional powers;

For each example of regime resistance identified within the analysis. Two research questions were considered:

a) What implications does the identified aspect of regime resistance have for the translation narratives used by different actors in the case study?
b) Is there evidence of any impact on actors' transition approaches from this regime resistance within the empirical data?

8.3. Empirical data

Empirical data for this chapter is formed of 29 semi-structured interviews with UK stakeholders, conducted between March and August 2015. The majority of interviews, each approximately an hour long, were conducted with actors who were directly involved in delivering or supporting DH development (at both the local niche level and the global niche level (Geels and Deuten, 2006). This selection of interviewees, primarily focusing on actors involved in or connected to the DH industry, meant that aspects of regime resistance were explored from the perspective of actors involved in DH development (niche-actors) rather than broadening the focus to a wider set of regime actors. The objective of the data collection was not to provide a complete picture of all aspects of regime resistance, but to highlight the elements that were most apparent and experienced by DH niche actors.

In addition, interviews were sought with key regime-embedded actors mentioned within niche-actor interviews. These were identified as gas distribution company representatives and new-build developer representatives. Gas distribution companies operated the dominant heat supply infrastructure within the

incumbent regime, and gas often acted as the baseline comparator for assessment of economic viability for a DH network (assessing whether the network was the best technology solution rather than whether it was financially viable). A number of gas distribution actors had also begun to express interest in the potential of DH as an application of their company's skill set. Three gas distribution actors were interviewed in total (GD1, GD2, GD3). The response of new-build developers to planning policy requiring installation of DH in certain situations was also an important concern of niche-actors. Interviews were sought with three distinct new-build developers, but no interview was granted in the timeframe of this work.

Local and global niche actor interview selection

At the local niche level, 16 interviews were conducted with actors involved in the local delivery of projects (covering 7 distinct local authorities and 6 private energy companies). Energy company interviewees represented a variety of company types, from large utilities with a range of activities apart from DH (referred to as members of the 'Big 6' energy supply companies in the UK), to specialised DH companies whose main focus was on the development and operation of DH schemes (EC1, EC2, EC3, EC4, EC5, EC6). Similarly, actors from a range of local authorities from across Scotland (LA1, LA2, LA3, LA4) and England (LA5, LA6, LA7) were interviewed, some of which already had operating DH schemes in their area while others were only involved in the planning stages of projects.

At the global niche level, formal interviews were conducted with 4 relevant public sector actors from regional and devolved governments (RA1, RA2, RA3)[15]. Interviewees also included a selection of consultants involved in supporting project development (operating under both for-profit and not-for-profit business models) (C1, C2, C3), and trade associations representing DH actors across the public and private sectors (TA1, TA2).

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[15] Although interviews were conducted with Scottish Government representatives, these were not transcribed for use in the analysis to maintain anonymity. Instead, the recently published Scottish Government Heat Policy Statement (Scottish Government, 2015) was used for analysis.

It was not possible to conduct interviews with representatives from the UK government due to unwillingness to participate during the timeframe of the interviews. Instead, recently published policy documents were analysed to obtain the formal policy narratives of national level actors (these documents consisted of two strategic heat policy documents (DECC, 2012a; DECC, 2013c), a policy document focusing on the future energy infrastructure investment requirements (DECC, 2015), and an evaluation report on the impact of the England & Wales-based local authority support programme, HNDU (CAG Consultants, 2015).

Structure of interviews

The interviews were based on a series of questions designed to explore key socio-technical dimensions: context / background of the actor and their activities; market drivers and challenges; local institutional / actor networks and influence; users / social / culture influences and perceptions; technological and infrastructural aspects; policy environment; and perceived tensions / risks posed by the incumbent regime. Questions sought to understand actors' perceptions of how change had taken place during their time working on DH, and the causes of that change. Drivers and visions were also explored, with particular attention given to exploring the actions being used to achieve these visions. Appendix G includes a detailed overview of the questions used to structure the interviews.

8.4. Results

8.4.1. Stage 1 of analysis: translation narratives of actors

Stage 1 of the analysis process showed two distinct sets of political narratives being deployed to support niche empowering processes; one set supporting a 'stretch and transform' approach and the other supporting a 'fit and conform' approach. The 'stretch and transform' approach involved a substantially increased role for local authorities for both coordinating and delivering citywide and flexible DH. The 'fit and conform' approach envisioned local authorities taking a less prominent role in delivery, and instead supporting and encouraging delivery by traditional private sector energy company actors.

The results of the analysis have been categorised into niche-actor types: public sector (made up of local and regional actors), private sector delivery actors

(energy companies), and other DH-niche actors (made up of consultants involved in supporting DH projects, and DH-focused trade associations). Presenting the narratives in these categorisations allows a distinction between the drivers of each actor type, and exploration of actor agency. Table 11 summarises the main narratives that could be observed in each category. The following sections give more details on each of these categories in turn, highlighting where narratives corresponded to practical activities, or where they remained as visions for a regime transition. Following this, section 8.4.3 goes on to present the results from stage 2 of the analysis, where aspects of regime resistance that were visible within the case study data were identified. It considers where these aspects might have impacted on the narratives and transition approaches identified in stage 1 of the analysis.

Table 11: Summary of narratives used by key DH niche actors for enabling translation of niche practices into the incumbent regime

'Stretch & Transform' narratives	**'Fit & Conform' narratives**
Public sector actors (local and regional authorities) • Local authorities need to play a strong role in energy planning for their area; • A degree of local authority ownership is important to retain influence over long-term expansion; • The private sector is a source of skills and expertise to enable delivery, as well as potentially a partner for sharing risk and benefits (although trust of private energy companies was often low); • Regional government can play an important role for providing support (through provision of resource, expertise and knowledge sharing) tailored to the specific context of that region.	**Public sector actors (local and regional authorities)** • The role of local authorities is to support low carbon energy development in their area by encouraging traditional UK energy system actors to develop DH through highlighting opportunities (using heat mapping, local development plans, and encouragement within planning policy); • Efforts focus on new build opportunities, public sector estates and social housing; • Local authorities are risk averse and unwilling or unable to borrow for delivering schemes themselves.
Private sector delivery actors (energy companies) • The current regulatory and policy context will not enable uptake of DH to a scale that delivers its full benefits; • Governments (local, regional and national), must act to de-risk DH investment; • A DH skill-base is developing in the UK, but faster growth in the sector is needed to be able to retain these skills. • Specialist DH companies doubted the skill-base of non-specialist energy companies.	**Private sector delivery actors (energy companies)** • We deliver reliable and profitable DH; • DH is a niche activity in the UK, but there is slow and steady growth of the sector providing for new-build developments; • We only invest our time, energy and finance into projects that are likely to succeed. We cannot justify exploring higher risk projects.
Other DH-niche actors (trade associations, and consultants) • A 'fit and conform' approach will not deliver the DH systems that we require for decarbonising our energy system; • A clear and stable policy approach and strategy is needed from the national government, with appropriate powers to enable its delivery.	**Other DH-niche actors (trade associations, and consultants)** n/a

Local and regional authority 'stretch and transform' narratives

Amongst the local and regional authority actors interviewed for this study there was a range of translation narratives used arguing for a spectrum of transition approaches. The difference between the approaches hinged on the extent to which a local authority should take a role in leading and coordinating development of DH. The examples of stretch and transform narratives used by the interviewees highlighted how they wanted to enable strategic coordination of DH development at the local level. This represents a radical change from the incumbent regime situation, which would require moving away from historically centralised coordination of the previous decades, back to the local level ownership and strategic control.

> *"We sold the concept of DH. Not just as an environmental thing, a fuel poverty thing, or a cost saving. It's the total concept in terms of local generation and bringing things back down to the local level […] Somehow that has caught the imagination of local government officers all over the country." [LA4]*

In the absence of specific planning or regulatory powers for energy planning, local authority actors sought to be a source of strategic coordination by having an ownership stake in new schemes (c.f. the 'strategic development approach' identified in the pilot study in chapter 5). This meant that they could influence or drive expansion of networks beyond the most profitable sites to cover a larger area, unlocking a wider set of benefits in terms of flexibility and affordability for residents. The focus of development was broader than making profit as a primary objective, and aimed to enable expansion of the scheme to deliver wider social and environmental benefits.

> *"We didn't want to just give a concession away, and then have a private sector developer just come in and cherry pick the best schemes. It was about wanting to work in partnership to develop a range of schemes, no matter how financially viable they were, for the wider benefit of the city."* [LA5]

> *"I think what the council would want to do is, in setting up the network, it would in some ways be a not-for-profit operation. But I think we would want to make some profit off it, so that we could use the profit to extend the*

> *network into the areas where there is maybe fuel poverty in the retrofitting side of it. Whether that is viable or not, we don't know yet."* [LA7]

Local authorities' relationship with private sector DH developers was an important theme within their narratives and range of approaches was evident. Access to the skill-base held by the private sector was important to enable scheme delivery. However, after a scheme was operational, some local authorities felt that it was important that private sector involvement was removed from ownership and operation to ensure that it would not be exploited to create profit without achieving wider social or environmental benefits. Other local authorities sought partnership with the private sector, rather than aiming to take complete ownership of new schemes. This reduced the risk to the local authority and also enabled access to valuable skills and experience of the private sector actors.

> **Wholly local authority owned:** "*The public sector is not in a position to roll out infrastructure of that size itself. But it should be the public sector saying to the private sector, go and do this. I need a pipe network here. Install my pipe network. There you go, well done. You've been paid and that's us done our business. We will now own, operate and run this."* [LA3]
>
> **Part-ownership with the private sector:** *"So it's how we have a blend of schemes over a long period of time that the private sector can invest in, and also the public sector, so that we can share the benefit. It's about shared risk and reward."* [LA5]

In addition, although local authority actors used strong 'stretch and transform' narratives and visions, this did not always result in successful delivery of that approach:

> *"I think that strategically, everyone agrees with me. Strategically, everyone wants to see it happen. Financially and legally, and commercially, different story."* [LA3]

Regional authority narratives

As highlighted in Chapter 7, regional public sector authorities (where they existed) played a positive coordinating role for local authority DH endeavours, enabling

access to resources and expertise that would not have been possible for one local authority in isolation:

> *"It's very much a partnership role and we are providing expertise and guidance where there are gaps in the public sector, or in other organisations as well. So we try to provide additional capacity, and knowledge and expertise where the local authority need to be able to develop their role within the energy sector."* [RA2]

The narratives of regional authorities responded to their local context. For example, the Greater London Authority (GLA) and the Scottish Government were both highlighted by actors as effective examples of regional level government leadership for DH growth, but took different approaches to providing strategic steer and support. For example, in the context of high land values and high demand for new-build development in the Greater London area, the GLA had decided to stimulate activity using strong local planning policy requiring DH connection in new-build developments. This had led to the establishment and growth of a number of networks, under a mixture of private and public-owned governance models:

> *"The best example is London, where there has been this very consistent approach at GLA level to have a clear vision and a strategy from their carbon targets, which leads to the decentralised energy targets, which leads to planning policy, which forces developers to build DH. I think that's a pretty successful story of how policy should work. And it's been there for 10 years now and been through a couple of mayors [… So developers] have now realised that it is here to stay."* [EC2].

In contrast, the context of Scotland required a different approach, given the lower land values in Scottish cities and towns compared to London. The Scottish Government had set targets for the amount of new installed DH capacity, and had a greater focus on fuel poverty reduction objectives than the GLA. The Scottish Government approach used a 'strategy support programme' for local authorities to bring about development of local heat strategies and stronger local leadership on projects. In addition, since heat policy was devolved to the Scottish Government,

the role of regulation for achieving strategic development and greater customer protection was beginning to be discussed; a significant step in a 'stretch and transform' approach.

> "As the market grows, the Scottish Government plans to develop appropriate regulation, commensurate with the scale of the heat market, ensuring both consumer protection and further industry development." (p.21, Scottish Government, 2015)

However, powers over regulation of the gas and electricity networks were still reserved to the UK Government. This meant that achieving a consistent approach to heat and the competing gas network was reliant on cooperation from the UK Government.

The 'stretch and transform' narratives at both the local and regional level emphasized the potential benefits of a strong local authority involvement in DH development. Under this transition scenario, local authorities were cast as empowered energy actors with the skills and capacities to choose to invest in energy infrastructure projects, independently or in partnership with the private sector. In practice, there was evidence of some local authority actors achieving elements of these visions as they developed projects, but for many these visions remained theoretical.

Local authority 'fit and conform' narratives

Local authority 'fit and conform' narratives emphasized their "risk-averse" [LA1] nature and lack of powers for energy planning.

> "*At the moment, our finance colleagues would not be interested in borrowing through the public works loan board. […] We'd prefer to do it through grants and attracting private investment."* [LA6]

They preferred other actors, such as the private sector or new-build developers, to take on the task of DH development. New build developments, in particular, were seen as crucial to establishing new DH schemes. Retrofit areas were perceived as too difficult and expensive.

> "*Developers are key. They are the main drivers behind implementing these proposals. […] If they don't go with it, and we can't make them, it becomes a very difficult thing to achieve."* [LA2]

Actors sought to use local development plans and planning policies to facilitate development of DH in new-build areas. However, many were reluctant to use strong requirements for fear of a challenge to the policy from developers, or a risk of driving development away from their area to other parts of the country. For example, one local authority described their DH planning policy as:

> *"It would be a promotional tool, if you like. Basically raising awareness that this is an opportunity. And future development going forward will be required to assess the possibility of incorporating some sort of DH into their proposal"* [LA1]

A key resource for enabling financial viability of new schemes was use of the public sector estates as heat demand anchor loads. Without the ability to require connections to schemes, persuading organisations with high heat loads to connect with a long-term contract provided crucial stability to financial business cases.

> "*In some way, the public sector has to lead this. If there are large, well located public sector buildings which have the potential to generate heat and they can feed in, then that should be considered."* [LA2]

In this 'fit and conform' transition scenario, actors focus on using the existing influence and powers they have to encourage others to develop projects. Private sector actors lead investment in DH infrastructure where it is profitable to do so. Local authorities assist through planning policy for new builds and commitment of public sector estates as heat anchor loads.

Private sector 'stretch and transform' narratives

This section contrasts these approaches with the niche-actor narratives from the private sector. These are actors who deliver provision of energy supply and energy infrastructure within the incumbent regime. All actors expressed some form of 'stretch and transform' narrative, although these were often cautioned with

comments that showed the potential for slow and steady continuation of the DH market in a 'fit and conform' scenario.

The 'stretch and transform' narratives of private sector energy company actors also advocated for a strong local authority coordination role but highlighted the lack of capacity in many local authorities to deliver this role at present.

> *"If local authorities actually had proper resources or a real kind of encouragement and license to borrow and invest. […] It seems hard to see how DH will get going [without this]."* [EC2]

There was a call for greater policy intervention at the national level in the form of regulation to enable requirement of connections and strategic growth of schemes, as well as incentives to drive growth in the DH market.

> *"I think the kind of over-arching one is that you can't really scale city-wide DH schemes, or even grow a market around DH within your nation, without applying regulation in an intelligent way."* [EC6]

In addition, actors highlighted the risk of losing skills within the sector if action was not taken in the near future and growth achieved.

> *"So we've got the challenge that at the moment, most schemes aren't quite competing in the market and skills building. If we don't have schemes happening over the next 5 and 10 years, we will lose that as people go on to other things, and find other things to do."* [EC5]

Private sector' fit and conform' narratives

Despite widespread use of 'stretch and transform' narratives focusing on local authorities taking a leadership role, private sector actors predominantly acted within a 'fit and conform' approach. Their narratives focused on emphasizing the competitiveness of DH in certain circumstances and the need for their involvement in projects to be profitable. This sought to create a more protected, lower risk environment for DH activities without their company having to take that risk on themselves. They emphasized that their companies required their DH activities to be profit making in the short-term and were not presently willing to invest for potential long-term gains.

> *"Ultimately, we have still got to be able to deliver profit. They won't keep driving our business if we don't deliver revenue and profit. It's not just a nice to have. We've got to justify our existence."* [EC5]

They foresaw that in a 'fit and conform' scenario that the sector would continue to operate as it had previously.

> *"It's always been a bit of niche activity. […] It's been quite refreshing really, to keep ticking along where it sits"* [EC2]

Their activities focused on new developments where they perceived low investment risk, particularly with projects in the Greater London Authority where there were strong planning policies for new builds, which required installation of DH.

> *"I think if you analyse where it's gone ahead, they have been the low hanging fruit that people have been prepared to support"* [EC3]

The long development times of DH projects meant that companies were keen only to expend resource and time on projects that they thought were very likely to come through to operation.

> *"These are chunky projects so there is quite a lot of resource that goes into just modelling them and doing the proposal and things. So that is a challenge for us. We want to try and avoid ones where the chance of winning business at the end it is small."* [EC2]

Other DH-niche actors (trade associations, and consultants)

There were also a number of non-public sector support networks involved in niche creation and development, such as consultants, public-private partnerships and trade associations. These actors each supported local actors in their work on DH development, either by supporting specific project development or acting as a form of trade association for public and private actors involved in the industry. Their interaction with multiple local actors enabled them to play a type of intermediary role between local level activity and national policy makers.

Narratives from these actors cautioned against expecting too much impact from local authority support mechanisms such as HNDU and the Scottish Government Heat Network Partnership (HNP).

> "*We get all of these feasibility studies but we lack the capability to implement them at wide scale. There is thought about this going on. I guess nobody knows quite, is it going to work out or not, or does every scheme have to take this organic slow growth?*" [C1]

> *"So, from my perspective I see the huge benefits of getting there, but no idea how we're going to get there. And I don't see anything that is really pointing in that direction at the moment. Because there is nothing. Lots of interest. A huge amount of interest. And I do see the potential for local authorities to really start to take back energy into municipal energy, but, yeah, I'm struggling with the kind of drivers for that."* [RA3]

Echoing the 'stretch and transform' narratives of local actors, this set of global actors consistently emphasized a need for more national level policy leadership.

> "*Consistency, strategic vision, stability, lack of uncertainty, would all help a lot. So something that said, kind of, look, we are going to be here from now and we're not going to change our minds unless there is a really good reason to do so. You don't get much of that in the UK."* [RA3]

> *"It's absolutely key that there is an overall strategy to know where you want to get to. And a confidence that if you start up you are actually going to get there. So you don't end up in in-between land. You've done the first phase that you always knew wasn't going to be particularly fantastic in terms of environmental or financial performance, but that somehow the whole strategy gets de-railed and it stops there. You are stuck with phase one which you always knew wasn't going to be great. And that then is seen, oh, that's DH."* [C1]

8.4.2. Discussion: narratives for a 'fit and conform' or 'stretch and transform' transition to DH?

The analysis of the case study presented here demonstrates the messy reality of how multiple niche and regime actors seek to influence the process of transition

with a range of political narratives (Smith and Raven, 2012). A variety of narratives on the extent of regime change required for a transition to DH were used by the public and private actors, although there was a general consensus that strong local public sector coordination was needed to achieve widespread uptake of DH. For some local authority actors in the study, this meant retaining an element of public ownership in networks in order to hold a direct influence within decision making for expansion and interconnection. For others, their role was to reduce risk and create an incentive for the private sector to take on a delivery and ownership role. For example, coordination from the GLA in London had led to strong and consistent local planning policies in many London boroughs for a requirement to install or connect to DH in new developments. This approach was supported by high land values and high demand for new developments and had resulted in what appeared to be the early stages of a successful 'fit and conform' approach. However, for local authority actors in different local contexts, this approach to driving development with planning policy did not seem a realistic approach.

In many ways, the private actor narratives supported local authority 'stretch and transform' visions, calling for stronger powers for local authorities to play a strategic coordinating role and facilitate new DH developments. Their long-term objectives ultimately sought to reduce the risk of project investment and achieve commercial rates of return. In contrast, local authority 'stretch and transform' narratives focused on achieving wider social and environmental objectives such as fuel poverty reduction, carbon reduction and customer protection alongside.

These differences in fundamental objectives for developing DH were an important distinguishing dimension between different actor narratives. Private sector actors held crucial capacities and skills required to enable delivery of projects, but did not feel able to go beyond delivery of “low hanging fruit” projects due to pressure to ensure sufficient financial return on their activities in the short term. Local authorities lacked many of the relevant skills and capacities held by the private sector. However, cooperation with the private sector was sometimes viewed with suspicion, with local authorities feeling they lacked the knowledge and skills to be able to adequately manage the tendering process to achieve many of their own objectives.

The diversity in the narratives used by niche actors across the sectors highlights the variety of directions that a DH transition could take in the UK. Therefore, for the purposes of this thesis, which seeks to add understanding to how a transition to DH can be governed, it is important to understand the extent to which regime resistance and lack of actor agency influence the narratives that actors use.

8.4.3. Stage 2 of analysis: assessing the influence and impact of regime resistance

This section presents stage 2 of the analysis, where the possible influence and impacts of regime resistance over actors' transition approaches are considered. Table 12 presents a summary of the forms of regime resistance that were observed in the case study data. These examples are not meant to form a complete list of all aspects of regime resistance within the case study, but just those observed in the data. For each form of resistance, the potential impact on DH niche empowering processes is considered, and evidence of existing impacts is outlined.

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Table 12: Forms of regime resistance to DH niche empowering processes, categorised by the four types of regime resistance identified by Geels (2014).

Form of regime resistance	Incumbent regime characteristics	Implications for DH empowering processes (and choice of translation narrative)	Observed impact of regime resistance?
Use of instrumental forms of power:	**Refusal by developers to incorporate DH into new developments** The need for new housing in many areas meant that housing developers were felt to be in a position of power to negotiate DH out of new developments. • Housing developer business models focused on getting the lowest land cost and highest profit per house. The inclusion of district heating instead of gas network infrastructure into new housing developments added an element of uncertainty to their activities and they resisted local planning policy imperatives to installing DH in new-build developments.	This resistance is detrimental to both types of transition approach, but particularly for 'fit and conform' approaches where the actors were seeking to use new-build developments as catalysts for network expansion in the future.	Some local authorities sought to support a 'fit and conform' transition, but were hindered by their ability to use planning policy. For example, one local authority described planning more as "a promotional tool" [LA1], rather than a stronger instrument for compelling new-build development to build DH.
	Transferring DH capital costs away from new-build house prices Where DH had been installed in new build developments, house builders sought to reflect DH capital costs within standing charges rather than house prices (as would have been done for the gas network and gas boilers). This ensured new-build house prices were lower at the point of sale and would sell easily.	This practice could lead to a public perception that DH is an expensive and undesirable heating option, undermining the viability of the technology in either a 'fit & conform' or 'stretch and transform' scenario.	Energy companies seeking to take on ownership and operation of DH networks in new developments noted this practice as a reputational risk to their business. *"It's a big problem if the energy prices get forced up, because then it causes a lot of complaints and so on. If you buy a property, you expect to buy the boiler as part of what you are buying. But sometimes effectively, people haven't been buying the DH as part of their first charge, they've been buying it as part of a high standing charge."* [EC3]

Form of regime resistance	Incumbent regime characteristics	Implications for DH empowering processes (and choice of translation narrative)	Observed impact of regime resistance?
Use of discursive strategies:	**Framing DH as impractical** Gas distribution actors emphasized the high costs and physical challenges of installing DH under roads. *"Physically, you could put an underground through London. But practically, from anchoring it in the trilemma point of view, is that really a sensible option? And once you've done that, what about the other 90% of the city? Great we've hit 10%, and of that 10% half are still on gas, and it's just cost us £240million. Which is as a unit cost for the incremental change is just absolutely astronomical."* [GD2] They added legitimacy to these arguments by highlighting their own expertise in installing and managing pipe infrastructure. [Note: Despite presenting arguments against DH, gas distribution actors were careful to stress that they were not wholly against DH in principle, and saw it as an area where their skills could be applied in the future if the market were to grow (although most were not actively exploring opportunities at the time of this study)]	These arguments undermine both transition approaches by framing DH as an optional infrastructure rather than having entitlement to space alongside other utility infrastructures such as gas networks or fibre optic broadband cables. Arguments made by experienced gas distribution actors also have the potential to increase niche actors' perceived risk of new DH projects, especially in the context of few existing schemes, with many decision makers acting without experience in delivering projects.	Many niche actors favoured new-build developments because they felt that retrofit was too complicated and high risk. *"[Retrofitting DH] is not something that is really at the forefront of our minds just now. There is a tendency to believe that retrofitting is more costly. I don't know if there is any fact for that at all."* [LA2]

Form of regime resistance	Incumbent regime characteristics	Implications for DH empowering processes (and choice of translation narrative)	Observed impact of regime resistance?
Use of discursive strategies (continued):	**Framing gas as a necessary part of a low carbon transition** Gas distribution actors emphasised the importance of gas for meeting peak loads and seasonal swings; the length of time needed for roll-out of large-scale DH; and the need for options for customers that do not want to connect to DH.	These narratives undermine the legitimacy of DH for either transition approach by highlighting the uncertainty involved in a change to DH, in contrast to continuing with the status quo.	These narratives had been explicitly recognised within national government heat policy: *"Particular areas of the country could see a strong role for gas networks in the long term, [...]. For example, future pre-combustion carbon capture and storage plants on the east coast could produce significant volumes of hydrogen overnight when it is not required for electricity production, and this could be fed into local grids to provide low carbon heat. […]. In rural areas, biomethane plants feeding into local grids could be a key part of the solution."* (DECC, 2015)
	Framing DH as something that customers do not want Housing developers sought to discourage planning policy requiring DH by arguing that customers did not want DH technology in their homes.		

Form of regime resistance	Incumbent regime characteristics	Implications for DH empowering processes (and choice of translation narrative)	Observed impact of regime resistance?
Use of material strategies:	**Funding for gas network innovation: exploring the gas network as an infrastructure for low carbon fuel distribution** Gas distribution companies highlighted the potential to make alternative use of gas network infrastructure for transporting biomethane or hydrogen fuels. *"The H21 project is anchored in the middle of the trilemma. So production, transportation and consumption. Actually production wise we've got all of this gas, transportation we've got a system already built that works perfectly for these huge inter-seasonal swings, but actually in consumption everyone is using gas. So if you can manage the carbon out of the gas before you burn it, you effectively can decarbonise heat without really changing the infrastructure."* [GD2] Innovation funding through the UK energy regulator (OFGEM) was being used to support pilot projects for both hydrogen and bio-methane options.	This form of resistance is particularly detrimental to 'stretch and transform' transition approaches as it undermines calls to commit to DH as a necessary part of the future low carbon heat supply on a large scale. Although funding was available for local authority activities through HNDU, this did not cover the capital costs of projects, making it harder for local authorities to get initial projects successfully operating.	The UK government's market-led policy approach avoided making a commitment to use of DH or gas in any particular areas.

Form of regime resistance	Incumbent regime characteristics	Implications for DH empowering processes (and choice of translation narrative)	Observed impact of regime resistance?
Use of broader institutional powers:	**Private sector focus on short-term commercial rates of return** Despite holding more of the required skills and expertise for practical delivery of DH than local authorities, private sector companies were unwilling to invest in projects that did not provide commercial rates of return.	This is a form of resistance primarily for 'stretch and transform' transition approaches, where local authorities would play a stronger role in development of networks. The lack of a skill-base in local authorities makes a 'fit and conform' transition much more likely, where private sector actors continue to lead on DH delivery where it can offer suitable commercial rates of return.	Despite various skills-building initiatives, local authorities were often perceived (by themselves and other actors) to lack understanding and skills to manage the risk of DH projects effectively. Some actors expressed a concern that lack of technical expertise was preventing effective procurement from the private sector of appropriate DH delivery services, leading to inefficient or more expensive schemes.
	Austerity agenda reduces local authority resources Budget cuts imposed upon local authorities from national government reduced the resources available for developing DH and hindered development of staff experience and knowledge due to high staff turnover.	The impact of local authority budget cuts made it more difficult for local authorities to politically justify taking on the risks of investing in DH schemes themselves. This is particularly detrimental to a 'stretch and transform' approach. *"If we are expecting local authorities to take this role on, then do we need to look systematically at how it is financed and whether it comes under a statutory obligation? Because they are about to get another shoo in. Whoever wins the next election. And it's hard for them to provide meals on wheels, let along commission feasibility studies for heat networks that might never happen."* [C2]	The impact of budget and staffing cuts on local authorities was cited widely as impacting on the resource availability for working on DH. Some actors saw austerity as a driver for local authorities to develop DH schemes that could reduce their background energy costs and potentially generate an income for the local authority. *"The municipal energy companies are […] a way that they can set up a trading arm and hopefully generate some surplus to feed back into the authority to stave off all of the cuts that central government are producing."* [TA2]

Form of regime resistance	Incumbent regime characteristics	Implications for DH empowering processes (and choice of translation narrative)	Observed impact of regime resistance?
Use of broader institutional powers (continued):	**Changing energy policy goals and measures** The lack of an established approach to energy decarbonisation at the UK national government level, and changing political priorities between energy affordability, security and decarbonisation had led to fast changing policy approaches and short-term measures. For example, the 2016 "Zero Carbon Homes" target was acting as a driver for installation of DH into new buildings alongside planning policy (Lovell, 2015). However, this target was removed before the target was realised, in July 2015. Where government grant programmes had been in place in the past their time frames had been too short to allow for the long development time of DH In addition, the policy culture of using a market-based approach to select the optimum technology innovations of the future was particularly challenging for DH as an infrastructure technology, competing against the already established gas network infrastructure and gas supply industry.	This policy context undermined niche shielding, nurturing and empowering processes for DH. The long development time of DH projects made DH particularly vulnerable to short-term changes in government policy and initiatives. The high upfront capital costs of DH as an infrastructure technology made it higher risk for potential investors making investment decisions in a fast changing policy context.	Actors felt that opportunities for development of projects had been missed as a result of the unpredictable national government policy approach: *"[It was] frustrating because under the rules of the capital modernisation fund you had to have delivery within 2 years. In the end it was extended, but at the beginning you didn't know it was going to be extended. So the extension came along, several extensions, but because they didn't know that it was actually going to chunter on until 2007, they were never able to plan during those 6 years, so it did enable one or two more schemes, but that was a major problem really. Was just the time scales.*" [C1] The market-led approach to policy meant that there was reluctance to use regulation within the policy for DH as well: *"The Government does not want to stop the growth of the sector through introducing unnecessary regulation" (DECC, 2013c)*

Form of regime resistance	Incumbent regime characteristics	Implications for DH empowering processes (and choice of translation narrative)	Evidence of the impact of regime resistance on DH development?
Use of broader institutional powers (continued):	**Differences in public sector procurement rules across institutions prevents public sector involvement in projects** Public sector estates such as hospitals, universities, and museums have the potential to act as large anchor loads with long term contracts to reduce the risk associated with the capital investment of a scheme. However, their focus on demonstrating "lowest cost" criteria at the institutional level, and working over different timescales, created barriers to their commitment to a DH project for heat supply.	The focus on individual rather than collective public sector institutions increases the uncertainty in project development and strategic planning for DH. This is detrimental to both transition approaches.	Challenges and delays had arisen for DH projects because of the differences in procurement rules and accounting standards between different public sector bodies, and lack of understanding of DH technology amongst senior decision makers.

Regime resistance and niche actor agency

Considering the analysis presented in Table 12, some of the identified forms of resistance are the result of the embedded institutional structures and cultures of the incumbent regime, whereas others are an active type of resistance driven by industry actors embedded within the incumbent regime seeking to further their own interests.

Embedded structural and cultural regime resistance impacted on different actors in different ways. Forms of regime resistance had a particularly high impact on local public sector actors. As new energy system actors, local and regional public sector organisations were promoted by actors across the sectors and geographical scales as having the potential to carve out a new role for themselves within a 'stretch and transform' transition. However, although some actors used translation narratives that promoted more radical transition visions, for the majority of actors in the case study, regime resistance prevented them from developing the agency to make these visions a reality. For example, the on-going austerity agenda represented one form of institutional power that severely affected public sector budgets and staffing levels, making it more difficult for actors in this sector to justify taking on new activities and responsibilities for an infrastructure technology with long development times and a need for on-going coordination and investment. Unpredictable national government energy policy added further risk for local authorities that wanted to invest resource and finance into encouraging DH - particularly since there was no indication of the level or type of DH needed across the energy system and a lack of detail about the future of the gas network. The lack of expertise and experience of DH in the public sector also made this new role challenging. In these examples, regime resistance was acting to prevent local public sector actors developing their own instrumental and material powers to act on a ‘stretch and transform’ transition approach.

In contrast, the private sector actors held capacity and skills to deliver DH projects, but their wider companies or investors used their broader institutional powers to uphold the incumbent regime, requiring commercial rates of return on short-term investments that many DH projects could not meet. In this way, further structural and cultural forms of regime resistance also served to reduce the agency of private

sector actors to actively support a ‘stretch and transform’ transition approach to DH development. Therefore, the limited agency of niche actors across the public and private sectors seemed to leave little alternative to a ‘fit and conform’ transition approach, except in exceptional circumstances relying on factors such as actors’ social capital (Hawkey et al., 2013).

More active forms of regime resistance to a transition to DH came from Great Britain’s reliance on gas for heating, and the business models of new-build developers. Gas distribution companies utilised multiple avenues to exert regime resistance to DH. They held material and instrumental forms of power, which they utilised to maintain the incumbent gas-based regime and, in the long term, the role of the gas network. For example they could access funding for innovation and held political leverage as a critical service provider in the energy system. They also used discursive strategies to support these ideas. For example, using narratives that framed gas and the gas network as having a part to play in a future low carbon heat supply aimed at UK government actors or large-scale energy companies and investors. These forms of regime resistance did not generally seek to put resistance directly on DH niche actors at this stage. However, with the limited agency and powers of local authority actors, these activities still worked to undermine the argument for a radical DH 'stretch and transform' transition and any moves to manage-away the gas network or implement supportive regulations for DH.

More active forms of regime resistance also came from new-build developers, who held strong instrumental power due to the need for new houses in many areas, and the jobs and economic growth that could potentially come with this development activity. Both local authority actors and private sector actors saw developers as using their positions of power to resist or undermine the case for DH in their developments.

Overall, the combination of these various forms of regime resistance limit the activities and general transition approaches that both public and private niche actors can take. In the context of a relatively stable regime, there are very few windows of opportunity for niche actors with limited agency to facilitate niche

processes and drive a more radical regime transition (Geels, 2004; Geels, 2014; Smith and Raven, 2012).

8.5. Discussion: lessons for governing a transition to DH?

This section considers the lessons from this analysis for governing a transition to DH. It also considers the implications of the work for this relatively under-developed area of the socio-technical transitions literature on empowering processes, actor agency and regime resistance.

The analysis showed that there were structural and cultural forms of regime resistance that acted to undermine the agency of niche actors, as well as more active forms of regime resistance from developers and the gas industry. The combination of this resistance worked to reduce the agency of both public and private sector niche actors to undertake activities that might support a more radical 'stretch and transform' transition. Many actors still used 'stretch and transform' narratives, but the reality for many was that these were unlikely to be delivered in practice without undermining of some of the powers deployed by regime actors to resist a transition. This supports the findings of Turnheim and Geels (2012), who argue that the causes of transitions are bi-directional, driven by destabilisation of an incumbent regime alongside the strength and attractiveness of an innovation. The long timescales of infrastructure lifecycles means that the gas distribution network is likely to be slow in responding to market signals. This destabilisation of the incumbent regime can create a window of opportunity for diffusion of an innovation.

Considering the policy implications of regime destabilisation within the case study, one potential option would be for the UK Government to play a role in addressing two key challenges:

(1) The systematic undermining of DH niche-actor agency (particularly of local authorities) for enabling large-scale, strategic development of DH across the UK;

(2) The lack of public and political debate about the need to move away from a gas-based heating system (and the possible role of DH for providing an alternative).

As suggested by Webb (2015) a form of positive regulation for DH could be one way to equip niche actors with greater powers to implement strategic plans for DH over the long term. Paired with the addressing of resource issues in local authorities, this could enable the scale of installation required to realise the full range of potential benefits of DH. Furthermore, a more balanced partnership between the public and private sector could be another important dimension in the context of liberalised energy markets, ensuring that private sector skills and capacities can be utilised whilst ensuring some strategic coordination for longer term, social and environmental objectives. This balance between government coordination and markets is particularly important for infrastructure innovations (Bolton and Foxon, 2015), where timescales are long, capital costs of projects are high, and market forces are weak and slow to respond.

Considering policy approaches for destabilisation of the incumbent regime, Turnheim and Geels (2012) highlight the importance of "cultural criticisms and political contestations of the existing systems" (p.49). In the case study, this could translate to a clear articulation by the UK Government on the future of the gas network and when and where change needs to take place, as well as greater stimulation of political and public debates about the future of gas-based heating systems. Stronger government intervention would mark a significant change in the policy approach for contexts such as Great Britain, where liberalised markets have been favoured over strong government intervention.

8.6. Chapter conclusions

This chapter has explored the political narratives used by actors in the case study to support niche empowering processes for a 'fit and conform' or 'stretch and transform' transition. The analysis showed how these narratives supported a range of different transition approaches. Some argued that DH could 'fit and conform' into the incumbent regime, and focused their activities on new-build

developments as catalysts for scheme expansion in the longer term and using local planning policy to encourage this approach. Others argued that a 'stretch and transform' transition was required with local authorities taking on new leadership roles to enable strategic coordination of DH development for large-scale schemes to enable the multiple types of benefits to the energy system and local area (economic, environmental and social). However, in practice, different forms of regime resistance worked to undermine the agency of both public and private niche actors to take actions to realise 'stretch and transform' approaches to transition.

By also analysing aspects of regime resistance, this chapter has demonstrated the limited agency of niche actors seeking to facilitate empowering processes. Regime resistance influenced actors' choices of translation approaches and their ability to deliver them by creating challenging institutional structures and practices, as well as presenting alternative narratives to low carbon heat transitions that undermined the argument for DH.

The work supports findings of Turnheim and Geels (Turnheim and Geels, 2012) that support for niche processes needs balancing with support for destabilisation processes of unsustainable parts of the regime. For Great Britain, it is argued that this would be supported by the UK Government policy approach moving beyond market-based approaches to policy, and moving towards introducing DH regulation that supports national, regional and local governments to take a stronger coordinating role. Alongside this, destabilisation processes could be supported by beginning to stimulate political and public debates around the need to move away from the existing gas-based heating supply, with eventual specific commitments for actions and a time frame from the UK and Scottish Governments. The work therefore argues that, without an increased intervention approach at the national government level, a transition to widespread integration of DH systems is unlikely to materialise in Great Britain at the scale required to offer wider energy system benefits of flexibility and security of supply.

This brings to an end the empirical results section of the thesis. The next chapter moves on to discuss the empirical findings and conclusions of the thesis as whole,

synthesising the empirical findings to consider lessons for governing a transition to DH. The findings are discussed in relation to the theoretical literature and the wider policy implications of the work. Finally, the chapter discusses where there is a need or opportunity for further research.

9. Discussion, further work, and conclusions

9.1. Chapter introduction

This thesis has explored lessons for governing a transition to district heating (DH). Drawing on a case study of Great Britain, it has examined specific governing measures as well as the influence of regime resistance over actors' agency to govern a transition to DH. This chapter now draws together the lessons from the preceding empirical chapters to consider the overall contribution from the thesis.

The chapter is structured as follows: Section 9.2 discusses four key themes arising across the empirical chapters and considers both their applied implications for actors seeking to govern a transition to DH, and their theoretical implications for the socio-technical transition literature. Section 9.3 discusses the limitations of the work in relation to application of the methods in practice and the scope of the findings. Section 9.4 then highlights areas where further research would be beneficial. Finally, section 9.5 concludes the thesis by summarising the contribution of the work to the overarching research question:

> What lessons can be drawn from a case study of DH development in Great Britain for actors seeking to govern a transition to DH as part of a low carbon energy system?

9.2. Applied and theoretical implications of the thesis

9.2.1. Nurturing processes for establishing local strategic development of district heating

A key challenge for actors looking to govern a transition to DH is how to achieve development of systems that are sufficiently flexible to be able to utilise multiple, and sometimes intermittent, low carbon heat sources. A form of local strategic coordination of DH development is likely to be required to achieve these types of systems (Chittum and Østergaard, 2014). The analyses in chapters 6 and 7

discussed examples of how governing measures designed primarily to support niche nurturing processes also had the potential to set the foundations to enable niche actors to support empowering processes. For example, informing stakeholder engagement with evidence from a heat map or sharing learning and best practice between actors can also be used by local authorities to take on a strategic coordination role. However, support for empowering processes relied on governing measures being designed to support development of actors' agency to take on this type of long-term role. The measures studied did not yet seem to be supporting these processes in the case study.

For example, Chapter 6 showed how heat maps had the potential to be used to help local actors develop DH beyond niche-based delivery in small, stand-alone schemes, by providing an evidence base for local strategic planning for large-scale scheme developments. However, heat maps were not yet commonly applied for this purpose in the case study because local authority actors lacked long-term and embedded resources, skills, and accompanying powers to take on this coordination role. Instead, use of heat maps was primarily limited to early niche creation activities such as providing an evidence base for identifying commercially viable projects. Funding was available for local authorities to commission technical consultants to carry out heat mapping and energy masterplanning studies. However, these support measures were not complemented by measures to build local actors' long-term capacities for applying heat mapping evidence to inform strategic heat plans. These governing activities, focusing on nurturing processes for delivering schemes in the short-term with commercial rates of return, did not develop niche actors' agency to take on a coordination role for strategic DH development for a low carbon energy system.

Chapter 7 also showed the potential of intermediary activities for supporting niche nurturing processes that built up actors' agency to take on a local coordinating role for a strategic response. This required multiple activities by different actors across different geographical scales. However, in the case study these different activities were not recognised or resourced equally. The analysis showed regime-embedded actors had capacities to deliver long-term, systemic intermediary activities to support the formation of a 'global' niche – enabling establishment of norms and

best practice across multiple niches. For example, national-level actors such as the Heat Network Delivery Unit within the UK Government and the Heat Network Partnership in Scotland played important roles. However, their activities alone were not enough to enable effective delivery of large-scale projects. Local intermediary activities were necessary, alongside activities at regional and national scales, for building local understanding and developing actor networks to enable local delivery of projects. The study suggested that niche actors such as local authorities often did not have access to sufficient resources to deliver consistent forms of intermediary activities and this kept their agency low for facilitating development of large-scale, strategic projects.

A lesson to draw from these examples is that governing measures which aim to support DH niche nurturing processes can be designed to also support niche empowering processes by building up the longer term capacities of niche actors for offering strategic coordination to DH development activities.

For example in the case study, the governing measures analysed in the empirical chapters could be supported by a long-term commitment of resource within local authorities to enable local capacity building (or potentially for regional authority actors where they exist). This could be in the form of a local (or shared regional) energy planner, responsible for strategic heat planning and coordinating delivery of such a plan. This could be supported or mandated from the national level with a statutory obligation on local authorities to develop strategic heat plans for decarbonisation, with associated powers to incentivise or mandate local stakeholders to comply. However, given the existing context of energy regulations and set up the energy market, these measures represent a radical step-change in the role of government in coordinating energy development. The austerity agenda within Great Britain also creates a significant political barrier to this type of approach, which would require additional resource allocation to local authorities.

An alternative approach observed within the case study for achieving this long-term dedicated resource was the setting up of a dedicated energy service company (ESCo) for the purposes of delivering low carbon heat and energy efficiency projects. Although this required investment of existing local authority staff and

resources for the initial set up, establishing a sustainable model of operation for the long-term could mean a dedicated staff resource that did not need to compete with other local authority priorities.

Theoretical implications and suggestions for further theoretical work

In their definitions of shielding, nurturing and empowering processes, Smith & Raven (2012) argue that niche processes are iterative, rather than taking place in a linear sequence. Taking this a step further, the examples above suggest that these processes could be more than iterative, and in fact form feedback loops. This is important to recognise, since activities to support particular forms of niche processes early on in a transition have the potential to prevent realisation of certain transition trajectories in the long-term. For example in Chapter 8, examination of political narratives as a form of niche empowering process showed that multiple niche actors articulated a need for greater local authority capacities to take on a stronger local coordination role in order to enable a transition to DH on a sufficient scale to realise its full benefits. However, without support for developing local authority capacities from a reasonably early stage, it is unlikely that local authority actors will be able to take on this new role. Any transition to DH would therefore need to take place without this local strategic coordination. This suggests that the timescales and order of governing measures used by actors could be an important aspect of governing transitions that would benefit from further research.

9.2.2. Coordinating governing measures across geographical scales and locations

Another key challenge for actors looking to govern a transition to DH recurring within the empirical chapters was the challenge of co-ordinating governing measures across geographical scales and locations.

Coordinating transitions across geographical scales

The case study highlighted some tension around the balance between devolution of powers to local level delivery actors vs. coordination of activities from centralised institutions, which had historically led energy system development. Local actors had a key delivery role since they held detailed local knowledge and could build relationships with key stakeholders to enable successful delivery of

projects by adapting delivery approaches to the local context. For example, Chapter 5 showed how local authority actors tailored their visions for DH according to local concerns and political priorities, offering a strategy for getting local stakeholders to commit to involvement in a project through dedication of resources or investments. Chapter 6 also showed the importance of locally adapted approaches, such as reflecting local decision criteria within heat mapping tools to enable better evidence for demonstrating the potential benefits of DH and use in stakeholder engagement for establishing new actor networks within the niche. However, solely local level perspectives on DH development had the potential to fail to address other wider energy system challenges.

Changes in the wider energy system have implications for the locations and nature of the type of DH that is required. For example, national planning can identify locations that might benefit from interaction between DH and the electricity system, to offer flexibility for integrating intermittent renewables through use of thermal storage. On the heat supply-side of DH design, national-level planning can make decisions about how to prioritise the use of biomass within the energy system as a limited resource. Should its use be restricted for transport, or is it acceptable to use it for electricity and heat generation in some circumstances? Approaches to governing decarbonisation in other areas of the energy system can also have implications for the viability of DH. For example, national energy policy decisions on issues such as managing away the use of natural gas and the role of the existing gas network infrastructure going forward has implications for the viability of local DH development plans. This suggests that, alongside local-level delivery actors, there is also an important role for national (and / or regional) level actors to support coordination of governing measures across geographical scales to facilitate delivery of wider energy system benefits with DH.

Practical measures to achieve this might be a requirement for integrated local energy plans; combining planning for energy efficiency, heat, electricity, and energy network management, or associated nationally agreed methods for project assessment. This type of integrated approach enables consideration of the impact of projects on other parts of the energy system. For example, Norway uses a licensing system for DH, and proposals for new projects are only granted

permission after they have been assessed to be the lowest cost option against other technology options (Bush et al., 2015). These types of planning and assessment approaches enable consideration of national energy policies within local activities, whilst also providing data that can inform national level policy makers about the mix of energy supply seen as viable at the local level.

There are also opportunities for policy measures that support business models and energy markets to better reflect the value of energy system flexibility provided by large-scale district heating networks with dimensions such as integrated short-term and seasonal storage, and multiple heat sources. For example, the existence of an established market for demand response services could incentivise the expansion and interconnection of DH networks.

Coordinating transitions across multiple geographical locations

Coenen et al. (2012) discussed how transitions can take different forms across geographical localities within what is perceived as the same socio-technical system. To some extent, these geographical differences are necessary to allow for differences in local contexts and challenges. However, variation can also result from actors in some areas having less access to key resources, skills and knowledge. In the case study there were multiple local 'niches' explored where actors were seeking to develop DH projects in various local contexts from large cities to small towns and sometimes even villages. These local actors had varying access to resources, knowledge and experience, as well as different physical contexts to contend with. This led to differences in actors' agency to take 'stretch and transform' approaches to their work on DH projects. For example, Chapter 8 showed how actors responded to regime resistance differently according to their local context, where the attractiveness of an area for developers impacted on local authorities' perceived influence to impose planning policies which required consideration of DH. Chapter 7 also showed the potential positive influence of regional authorities in supporting DH development with intermediary activities and pooling resources. However, although some regions had formed partnerships aiming to facilitate low carbon investment across multiple local authorities, others did not have such support. Supporting the arguments of Coenen et al. (2012), this work suggests that without some form of coordination from regional or national

level actors, there is potential for geographical unevenness in transitions where areas with potential for DH do not have local actors with the capacities to facilitate development (Coenen et al., 2012).

Examples of activities that could help national or regional actors to deliver this important role could be training programmes or funding to support access to and development of expertise, particularly targeted at areas that are struggling to deliver on strategically identified project opportunities. In the case study, the UK Government used the Heat Network Delivery Unit to provide aspects of this type of support. In Scotland, the Heat Network Partnership played a similar role, and also ran a series of training workshops focused on DH strategy development. Furthermore, national technical standards for projects, and customer service standards, ideally embedded within regulation are another example of ways to develop some consistency in how a technology is delivered across different geographical localities.

An overall lesson to draw from these discussions on geographies in transitions is that governing measures for DH can benefit from coordination across geographical scales and locations. At the time of this study, the UK had no formal means of coordinating local heat planning and delivery of projects to meet national system challenges. Local authorities also had differing levels of resource and capacity, which resulted in patchy and uneven activities for DH development, and sometimes no activity at all.

Achieving more consistent and strategic development across different localities is likely to require local authorities to possess not only resources and capacities, but also powers to incentivise or to enforce delivery of strategic plans for DH (whether they are driven by local or national priorities). This could be in the form of 'enabling' regulations; for example, the Danish Government's Heat Law grants Danish municipalities the power to require consumers to connect to DH networks in specified heat zones (Danish Energy Agency, 2005). In the long term, it is likely that it would also be necessary to create a formal link between local delivery approaches and national strategic energy plans, to ensure that delivery at the local level also meets national energy challenges.

However, a key question arising from this suggestion is how is a balance achieved between local and national visions? How are compromises reached if local and national actors' transition visions are not compatible? Does coordination across geographies need to take place throughout all of the transition process, or could geographical unevenness of transitions be useful for demonstrating the potential of an innovation in the early stages? These questions bring out the inherent politics of governing transitions and the imbalance of actors' agency between the niche and regime. Achieving coordination across geographical scales and locations is likely to require cooperation and compromise between niche actors and actors embedded within the incumbent regime. However, actors do not enter negotiations with equal access to resources and power (Shove and Walker, 2007) and this could lead to watering-down of niche-actor transition visions. These issues are discussed in more detail in the next section.

9.2.3. The role of compromise and cooperation in governing of transitions

The previous two sections have discussed lessons about the design of DH governing measures: (i) that governing measures can be designed to support niche empowering processes by building up the longer term capacities of niche actors for offering strategic coordination to DH development activities; and (ii) that governing measures for DH can benefit from coordination across geographical scales and locations. However, both of these statements raise questions about who and what influences the design of these measures. Where do resources to support their implementation come from and who decides where resources are allocated? The design of governing measures is a political process and actors require forms of power and agency to argue their case, which in many ways are determined by the incumbent regime and regime actors (Hodson and Marvin, 2010; Smith et al., 2005). There is an inevitable compromise between different actors' transition visions. However, it is important to recognise that compromise in niche actors' transition visions could undermine the ultimate goal of creating a low carbon, affordable and secure energy system and mitigating climate change. Finding a way to increase niche actor agency in this process of compromise is therefore important.

This section discusses two key dimensions to actors' agency that recurred as themes throughout the study: (i) actors' practical capacity to govern for a radical transition; and (ii) actors' freedom to express visions for a radical transition. Within the case study, actors' practical capacities were distributed unevenly across different actors. For example, local authorities had capacities to connect with local contexts and to enable cooperation between the local actors needed for delivery. However, most did not have access to sufficient skills and resources, which were required to enable both short-term delivery of DH projects and strategic long-term delivery. Skills and resources resided primarily with private sector actors who possessed greater experience of energy project delivery and energy supply activities. National government also held key capacities such as abilities to set policy incentives or taxes, as well as powers of regulation (both to support strategic DH development, and also over the terms of operation of the gas sector). A combination of these practical capacities is required for successfully delivery of DH. It could therefore be beneficial for governing measures to focus on developing practices that encourage cooperation between these different actors. However, achieving this cooperation between public / private, and local / national authority actors is likely to require some form of power struggle and compromise between actors' visions, objectives and their political freedom to support more radical visions.

The empirical studies revealed how actors expressed varying levels of radical transition visions. Local authorities were new actors in the energy system and they had the freedom to present a radical transition vision without undermining any existing activities or responsibilities. Private sector and national government actors, on the other hand, were more embedded in existing practices. Chapter 8 showed how the established business models of private sector energy companies, as well as the project financing options available to actors within these institutions, prevented them from investing in DH projects for long-term development of the sector if they did not offer commercial rates of return in the short-term. National government actors had not yet seriously tackled the politically sensitive question of the future of the gas industry within heat supply. They were also restricted by the austerity agenda and cuts to public budgets. Achieving cooperation between

these ranges of actors necessarily requires an element of compromise between the more radical transition visions, such as those held by some local authority actors, and the less radical visions of actors who hold key resources and capacities to support delivery.

There is not a general lesson that can be drawn from these discussions for governing a transition to DH. However, this case study shows how governing a transition to DH in the context of liberalised and privatised energy markets is likely to require some form of cooperation across the public, civic and private sectors to enable access to skills and resources for delivery of projects, whilst also embedding capacities for long-term strategic development of the system. In the case of Great Britain, there were clearly opportunities for greater cooperation between local authority and private sector niche actors that might help to overcome certain elements of regime resistance. These actors shared many of the same elements of 'stretch and transform' visions for DH, but had not yet established trusting ways of working together for mutual benefit.

Enabling these sets of actors to work together on project delivery, could support stronger delivery of 'stretch and transform' actor visions. For example, forms of DH regulations that de-risk project investment and enable development could be a way to establish these necessary cross-sector working relationships.

An approach to incentivise the private sector to lead on development might involve granting local authorities the powers to require connection to DH networks in strategic locations, thereby reducing the risk associated with predicting heat sales over the long financial payback periods for many projects. This could open up the capacity of private sector actors to lead on development, with local government retaining the influence to drive development beyond the most commercially attractive sites.

Alternatively, an approach to support local authority ownership could be through establishing trusted approaches to procurement, as well as trusted business and ownership models for DH. In the case study, work on establishing a DH procurement agency had begun, led by Greater Manchester Authority. Best practice in DH business models has also been a key area of interest, for example,

the Scottish Futures Trust published guidance on DH business models (Scottish Futures Trust, 2015). However, a local authority's willingness to take on financial debt was still a key issue in the case study. Some local authorities were limited on the amount of debt that they could take on within each financial year (based upon political policies of their authority area), so were restricted in their opportunity to take forward an investment. Grants and low interest loan schemes could provide a means to overcome these issues in local authorities, or alternatively reduce the investment risk associated with projects with longer payback periods for the private sector.

Finally, as was discussed in Chapter 8, regime destabilisation processes (Turnheim and Geels, 2012) offer another policy objective which could reduce the powers of regime actors in this process of negotiation. In the case study, national government actors have a crucial role to play in facilitating commitments to more radical transition visions by starting public debates around the future of the gas network in a low carbon energy system. Beginning the process of destabilisation of the incumbent gas-based regime therefore offers an important opportunity to remove some of the key barriers to DH development.

Theoretical implications and suggestions for further theoretical work

The roles of transition visions have been explored in various guises throughout the thesis. The first pilot study conducted for the thesis, presented in Chapter 5, began by exploring the transition visions held by local authorities within the case study. The themes of actor agency and political negotiation in defining transition visions and corresponding approaches to governing transitions have now been discussed as part of this chapter. Many of these themes support the existing innovation literature on visions in transitions. Visions are seen as 'bids' for political support and allocation of resources (Berkhout, 2006) and actors pragmatically compromise through the process of delivery – potentially losing many of the sustainability benefits offered by the original vision (Eames et al., 2006). However, one aspect that has not already been considered within this section of literature is in relation to the influence of the wider regime dynamics and destabilisation processes.

As discussed in the previous section, creating debate around visions for destabilisation of unsustainable parts of the incumbent regime offers an opportunity for alternative actors' visions to gain support and increase niche actors' agency for driving a more radical transition (Turnheim and Geels, 2012). Cooperation between different actors who hold complementary capacities also offers an opportunity to increase niche actors' agency. In these scenarios, niche actors are adapting their visions to respond and capitalise on regime dynamics and tensions. More radical transition visions have a greater chance of being realised when they exploit existing tensions in the regime (Smith et al., 2005). Geels and Schot (2007) presented a typology of transitions using the multi-level perspective that recognised specific situations where regime and landscape dynamics could enable a transition to take place. Through this typology, they argue that the context of the regime and landscape influences the most effective approach to governing niche processes. This suggests a potential area for further development of the literature on visions for innovations could focus on how actors can use visions to strategically respond to opportunities presented by developing regime tensions, or to further magnify these tensions elsewhere in the system.

9.2.4. Relevance for governing low carbon transitions beyond district heating

Although the focus of the thesis has been on governing a transition to DH, these lessons have relevance to wider aspects of governing of low carbon transitions more generally. The characteristics of the case study are shared by a multitude of other technologies and contexts. For example, the decentralised nature of DH is critical to many of the lessons on governing to build capacities for long-term strategic coordination of technology development. This is relevant to technologies and programmes that require a form of coordinated local delivery to achieve their maximum impact. Examples might be delivery of household energy efficiency schemes, developing local transport solutions, and behaviour change campaigns. In all of these examples, similar tensions of governing across geographical scales are apparent, where there needs to be a balance between empowered, locally-connected delivery actors and nationally coordinated action to meet national energy challenges and ensure even delivery.

The characteristics of DH as an infrastructure technology with high upfront capital costs and a potential need for alternative business and financing models also make the findings relevant to other infrastructure delivery within low carbon energy. For example, the key role of local, regional and national governments in providing a form of strategic coordination role has been recognised in another study by Bolton and Foxon (2015). They argued that governing of infrastructure transitions more generally requires a stronger government coordinating role, moving beyond market-based approaches to policy, and regulating to reduce the risk associated with projects. A beneficial area of further study would be to explore in more detail the relevance of the lessons drawn here for some of these other technologies, and how the transition pathways of these other low carbon energy innovations might co-evolve and influence one another.

9.3. Limitations of the thesis

This section discusses the limitations of the research approach used within the thesis, and the implications of this for the findings overall. Reflecting upon the research process as a whole, the following key limitations have been identified and should be borne in mind when considering the thesis results:

Scope of the case study

- The use of a single-country case study as the empirical basis of the research means that theoretical contributions drawn from analysis of the case study would benefit from wider empirical testing for their relevance to different contexts. As was discussed in the methodology, the focus on the UK provides an example of a developed country with a highly centralised energy system and a liberalised energy market. The findings of a similar study in a developing country or a more coordinated or decentralised energy market may suggest alternative perspectives for the literature.

- Similarly, the case study examines only one technology - DH. As was discussed previously in section 9.2.4, the findings are potentially relevant to a much wider group of innovations for low carbon energy. However, they would benefit from further testing with technologies beyond DH.

- Perhaps most importantly, the focus on a single energy technology within the case study considers the challenges of integrating one new type of innovation into the energy system. However, the single-technology focus also does not enable consideration of interrelations between technologies within the energy system. For example, developing local authority capacities for coordinating strategic delivery of energy efficiency measures or low carbon transport innovations, could also support delivery of DH networks. Alternatively, focusing on hydrogen or biogas fuels supplied within existing gas network infrastructure could undermine the case for DH in many areas. There is a significant potential to draw further lessons for governing low carbon transitions by considering how development of a particular combination of innovations, or actor capacities, could mutually support one-another.

Analytical focus at niche-level

- This work has focused on niche level governing processes. Although it has considered the influence of regime resistance over actor agency in the delivery of niche empowering processes, greater consideration of the influence of both regime and landscape dynamics from the multi-level perspective would be beneficial. Suggestions for further work on this aspect of the study are included in section 9.4.

Selection of research participants

- The majority of research participants were local or global niche actors involved in supporting the development of DH projects. For example, interviews were not conducted with local authorities' actors who were not actively engaged in DH development (of which there were many across the UK). This approach had the potential to miss key challenges to a DH transition, such as what happens for geographical areas where there are no local actors in a position to lead the delivery of niche processes. Therefore, the work has only considered certain aspects of governing niche processes for transitions, and the findings should not be considered as comprehensive or sufficient to drive a transition on their own.

- The research methodology set out to consider specifically how a transition to a specific technology could be governed (DH in this case). This set up meant that the study did not consider the full range of alternative low carbon transition visions for decarbonisation where DH was not featured. Alternative visions were restricted to those identified as providing direct resistance to the effective delivery of niche processes within the case study, represented by the gas distribution company actors. The influence of competing decarbonisation visions could present a significant resistance to governing processes for a transition to a specific technology, and this would not necessarily be reflected within data predominantly focused on niche actors. Therefore, as was noted in chapter 8, the study does not reflect all forms of regime resistance influencing transition processes, but reflects those articulated by the actors interviewed.

- In addition, there were a number of key actor perspectives that were not reflected directly in this study. In particular, housing developers and domestic heat users were not included. Both of these actors were identified within actor interviews as sources of risk where a transition to DH might be undermined. Although interviews were sought with housing developers, actors did not respond to invitations to participate in the research. In the case of domestic heat users, these actors were excluded from the study due to limitations of time and resource. This dimension is highlighted as an important area for potential further work. Given these restrictions in data collection, therefore, interpretation of the results should take into account that some key actor voices have not been directly represented.

9.4. Suggestions for further applied work

Considering the reflections made within the previous sections, the following suggestions for further work are made:

Consideration of how niche processes can be governed for multiple, interrelated technologies

As mentioned previously, it would be valuable to expand the focus of this study on DH to consider multiple low carbon technologies, and their inter-relations across the energy system. Even the single-technology focus of this case study has highlighted potential system-wide benefits offered by DH by enabling use of thermal storage for managing challenges of electricity grid capacity and balancing with intermittent renewable electricity generation. Given that multiple technology transitions need to happen simultaneously for climate change mitigation, a useful research question for further work would be: How can multiple technology transitions be governed together? (as previously noted by Geels (2011)).

Technology user perspectives

This study did not explore the influence of heat user perspectives in governing transitions. However, several actors identified this as a key risk to the future development of the industry. A valuable dimension of further work would therefore focus on user perceptions of the technology and how these might be more explicitly factored into governing of niche processes for DH. Foxon (2011) highlighted this need for greater consideration of technology users within the multi-level perspective conceptualisation of transitions. Applying Foxon's co-evolutionary framework might be a potential theoretical approach for giving greater consideration to technology users in transition governance.

Governing for radical regime change

A key criticism of the socio-technical transitions literature has been the treatment of actor agency and politics within transitions. Although the present work has made some contributions to this area of the literature, there are still more aspects to address. A key area highlighted in this work was the issue of compromise between different actors' visions for a transition. It is possible that incremental transitions will be too slow to decarbonise global activities on the time-scales required to mitigate the most dangerous effects of climate change. Therefore, understanding how it is possible to influence this balance to enable faster and more radical transitions is important for mitigating climate change. As chapter 3 outlined, the literature to date has highlighted the potential of cities or regions for demonstrating the potential of more radical transition pathways, adding

legitimacy to that transition vision for the wider system (Hodson and Marvin, 2010). This could also be possible at the country-scale, where a national-scale transition could act as a successful example for supporting other national transitions[16]. A significant area of further work would be to explore options for governing transitions to enable more radical versions of transition pathways.

9.5. Thesis conclusions

This thesis contributes lessons for actors seeking to govern a transition to DH as part of a low carbon energy system. Joining the debates in the literature around the governing of transitions, this work has taken the approach that a transition to low carbon energy will not happen within the timeframes required for mitigating the most dangerous effects of climate change without some form of governing from actors within the system. The work has considered the roles of actors from across the sectors; recognising that governing of a transition cannot be led by government alone. It has drawn on theories of socio-technical transitions to enable consideration of the interactions between the complex social norms and practices that develop and embed around an incumbent technological configuration, and the resulting resistance that forms to the introduction of new technological innovations. Given the chosen case study of Great Britain where DH is still in the early stages of development, analysis focused on developing relevant lessons for governing niche level processes.

The thesis has explored three aspects of governing a transition to DH, building on the findings of an initial pilot study examining the visions and delivery approaches of key local authority actors within the case study. The work interrogated the role of heat mapping tools in supporting niche nurturing and empowering processes, connecting the literatures on tool-use in policy making and governing transitions for the first time. It showed that the functionality designed into heat mapping tools could better support niche nurturing processes by reflecting the priorities of local

[16] The Danish Government attempted this approach through a programme run by the Danish Energy Agency. As a country with widespread DH and wind power integrated into their energy system, the government ran a project which attempted to share experience and expertise with other countries seeking to make a similar transition to using these technologies.

niche actors to support value demonstration and establishment of new actor networks. The tools also had the potential to inform strategic planning for DH and support niche empowering processes, but only when systematically embedded into use by actors with associated resources and powers.

The role of intermediaries in supporting niche nurturing and empowering processes across geographical scales was also explored, showing that the role of intermediary actors across geographical scales evolves as an innovation develops and becomes established; potentially supporting both nurturing and empowering processes. Activities at different geographical scales served different purposes in supporting a transition, but these were not recognised or resourced equally across the case study. In particular, local authority niche actors did not have access to sufficient resources to deliver consistent forms of intermediary activities and this prevented them from playing a role in facilitating strategic development of projects.

In the final empirical chapter, the work explored some of the impacts regime resistance on actors' agency to determine their approach to governing transitions. Picking up on discussions in the previous chapters and previous literature on the relationships between niche and regime actors and access to resources, this chapter explored the political narratives used by public and private actors across the case study to support their particular transition visions. It showed that actors' choices on governing approaches were influenced by the context of the resistant regime and agreed with Turnheim and Geels (2012) that successful governing of a transition required not only support for innovations through niche processes, but also needed balancing with incumbent regime destabilisation processes. A transition to strategic, large-scale delivery of DH systems in Great Britain is unlikely to materialise within the timeframe required for mitigating climate change without some form of government intervention to destabilise the incumbent regime alongside support for niche processes.

Drawing together some of the key themes that arose across the empirical chapters, this chapter has considered the overall lessons from the thesis for governing a transition to DH. As has been recognised previously in the literature on governing

transitions (Schot and Geels, 2008), focusing on niches alone is not sufficient to govern a transition. For example, it has already been discussed how destabilisation of unsustainable parts of the incumbent regime has a crucial role to play. For DH, one way to drive this process of destabilisation could be by establishing a narrative about the need to manage away existing fossil fuel-based heating technologies in order to create tensions in the incumbent regime for niche actors to exploit. In the context of liberalised markets, this is likely to need national governments to take a leading role in this process.

The role of DH governing activities to support niche processes is therefore to develop the readiness of niche actors across geographical scales to exploit tensions in the incumbent regime – particularly the readiness of actors at the local level. The capacities of local actors are a crucial part of being able to successfully adapt DH delivery models to suit differing local contexts. Regional and national actors can support local delivery, but cannot replace the need for some form of locally-led strategic coordination for achieving the benefits offered by large-scale DH systems. Niche-focused governing measures need to support systemic embedding of key resources, skills and actor networks at the local level.

In the context of liberalised energy markets, delivery of DH is also likely to require a means of enabling more effective and trusting cooperation between public, private and civic actors to combine the distinct capacities held across these different sectors. Establishing mechanisms and processes that allow this cooperation to take place in an effective manner that does not undermine the capacity for local strategic coordination of DH is likely to be a significant challenge, and one that would benefit from further research.

In summary, governing a transition to DH requires a combination of governing activities to support niche processes, alongside governing activities to bring about destabilisation of unsustainable parts of the heating regime. Local strategic coordination is critical to enabling development of schemes at sufficient scale and in appropriate locations to access many of the benefits offered by DH to a low carbon energy system. Therefore, niche processes need to simultaneously develop local capacities and agency for strategic coordination, as well as enabling cross-

sector cooperation between actors, who hold key skills and capacities to support delivery. The inherent politics of designing and delivering governing measures will undoubtedly require pragmatism and compromise from niche actors to achieve cooperation and access key resources. However, too much compromise away from local 'stretch and transform' visions for DH could restrict the scale of DH that can be achieved and undermine the whole function of DH within a low carbon energy system. For DH to make a significant contribution to a low carbon energy system, a clear and long-term commitment from national governments is likely to be needed to offer local resourcing, and implement enabling regulations and policy to support both niche processes and destabilisation processes.

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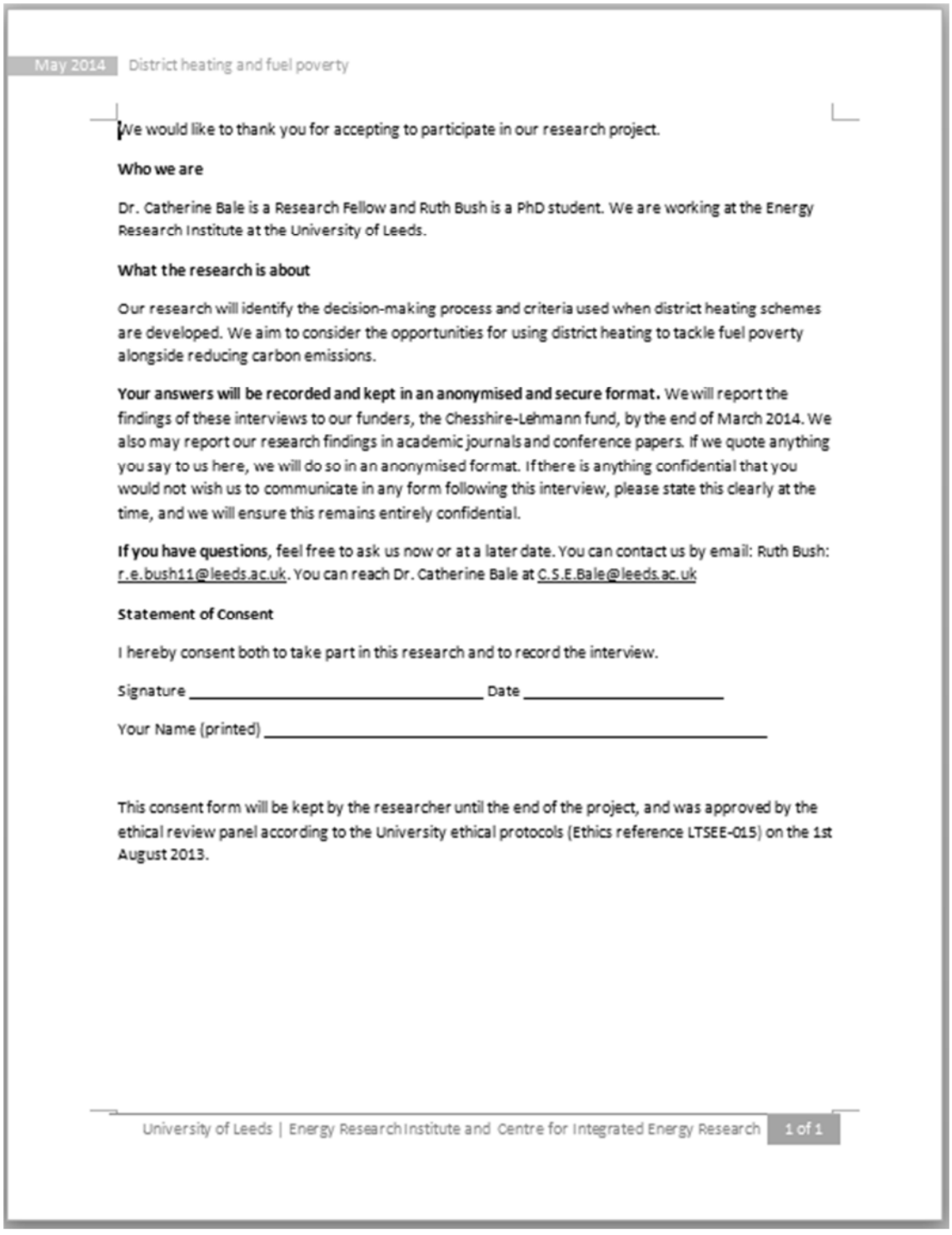
Appendices

Appendix A List of industry events attended during the course of this research

- Association of Decentralised Energy – Annual Heat Conference 2012, 2013, 2014
- EcoBuild Green Building Conference, 5-7 March 2013, London
- Vanguards Network Workshop: - Next steps in financing district heating, 21 November 2013, Glasgow
- UKDEA conference, 12 November 2013, Coventry
- National Energy Action National Conference 2013, 2014
- Global Energy Systems Conference, 26 – 28 June 2014, Edinburgh
- Euroheat & Power District Heating Summer School, July 2014, Helsinki, Finland.
- DHC+ conference, September 2014, Stockholm, Sweden.
- Stratego Project coaching sessions – October 2014 (Edinburgh), September 2015 (Aalborg, Denmark).
- All Energy conference, 4-5 May 2015, Glasgow
- Scottish Government / Danish Energy Agency study visit for local authority planning officers, 18 – 20 May 2015, Copenhagen, Denmark.
- Scottish Heat Network Partnership Strategy Support Programme Workshops, June, 2015, Inverness and Edinburgh.
- iBUILD Project (Infrastructure Business Models, Valuation and Innovation for Local Delivery) Stakeholder Event, November 2014, Newcastle

Appendix B Ethical consent forms

Phase 1 of data collection



May 2014 District heating and fuel poverty

We would like to thank you for accepting to participate in our research project.

Who we are

Dr. Catherine Bale is a Research Fellow and Ruth Bush is a PhD student. We are working at the Energy Research Institute at the University of Leeds.

What the research is about

Our research will identify the decision-making process and criteria used when district heating schemes are developed. We aim to consider the opportunities for using district heating to tackle fuel poverty alongside reducing carbon emissions.

Your answers will be recorded and kept in an anonymised and secure format. We will report the findings of these interviews to our funders, the Chesshire-Lehmann fund, by the end of March 2014. We also may report our research findings in academic journals and conference papers. If we quote anything you say to us here, we will do so in an anonymised format. If there is anything confidential that you would not wish us to communicate in any form following this interview, please state this clearly at the time, and we will ensure this remains entirely confidential.

If you have questions, feel free to ask us now or at a later date. You can contact us by email: Ruth Bush: r.e.bush11@leeds.ac.uk. You can reach Dr. Catherine Bale at C.S.E.Bale@leeds.ac.uk

Statement of Consent

I hereby consent both to take part in this research and to record the interview.

Signature _____ Date _____

Your Name (printed) _____

This consent form will be kept by the researcher until the end of the project, and was approved by the ethical review panel according to the University ethical protocols (Ethics reference LTSEE-015) on the 1st August 2013.

University of Leeds | Energy Research Institute and Centre for Integrated Energy Research 1 of 1

Phase 2 of data collection

Research Participant Informed Consent Form
Workshop on district heating

The Research Councils and the Universities participating in this project attach high priority to the ethical conduct of the research. Please read the project information and consider the following points before signing this form.

Who we are?
We are a research team from the Universities of Leeds and Newcastle.
What the research is about?
This research aims to investigate the decision processes involved in the development of district heating schemes.
What we aim to get from the workshop?
By the end of this workshop, we hope to get a clearer understanding of the role for local actors in delivering district heating schemes to inform further research.
We are holding this workshop under the *Chatham House Rule*, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.
See more at: http://www.chathamhouse.org/about/chatham-house-rule#sthash.wKQNH6N9.dpuf

Some of the sessions will be recorded (written and audio) and kept in an anonymised and secure format. This written work may include quotations from the semi-structured conversations but individual identities will always be rendered anonymous. Any audio recording will only be used for transcription purposes and will be destroyed once this process has been completed. The findings of the research will be used for academic purposes and by other interested organisations. Research findings may be published and used for teaching and research training. We may report the results of these interviews in academic journals and conference papers; if we quote anything you say to us here, we will do so in an anonymised format. If there is anything confidential that you would not wish us to communicate in any form following this interview, please state this clearly at the time, and we will ensure this remains entirely confidential.
If you have questions, please ask the researchers any questions you have now. If you have questions at a later date please contact Ruth Bush r.e.bush11@leeds.ac.uk

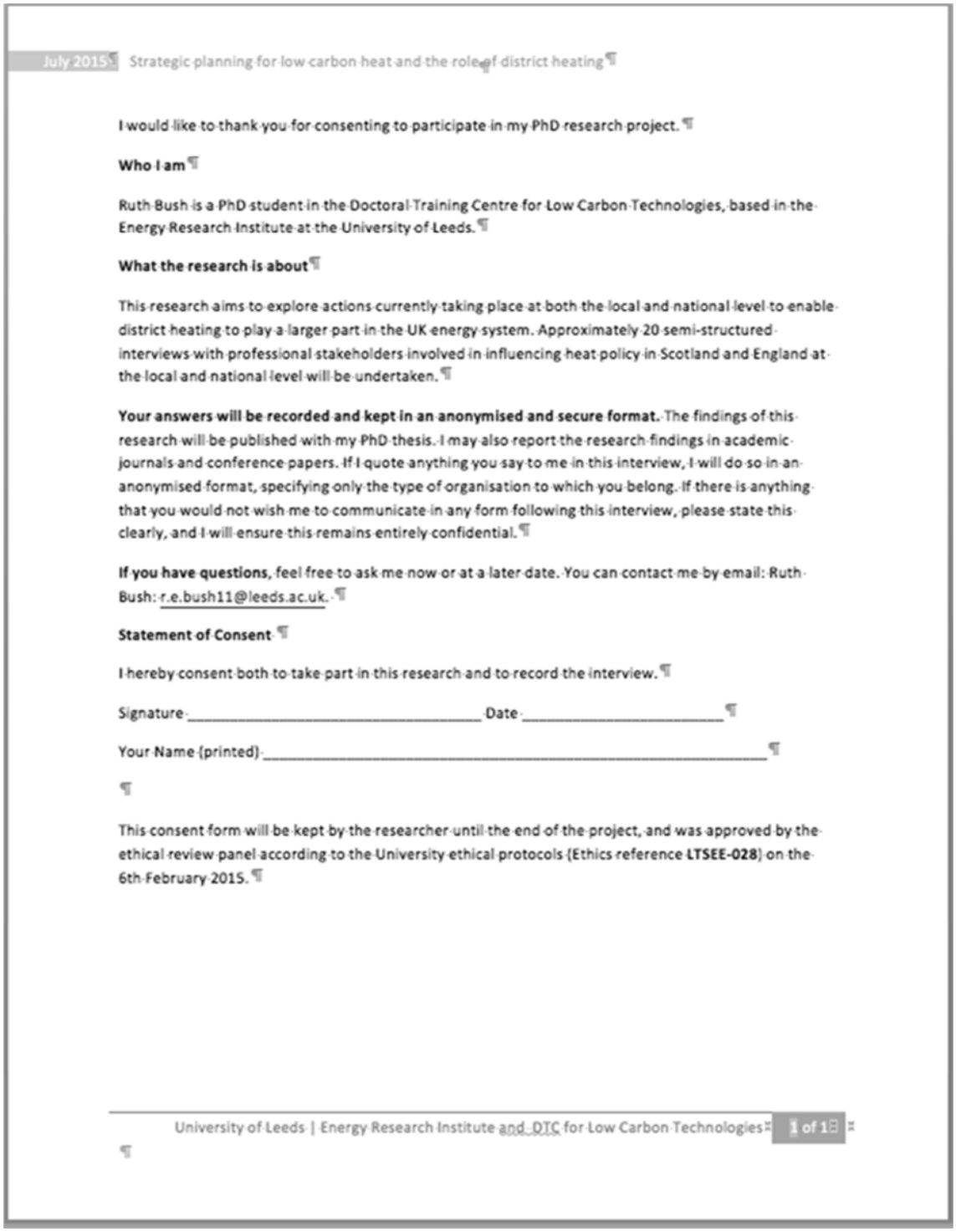
- I confirm that I have read and understand the information explaining the above research project and I have had the opportunity to ask questions about the project.
- I agree for the data collected from me to be used in relevant future research in an anonymised form.
- I agree to take part in the above research project.

Name of participant	
Participant's signature	
Date	
Name of lead researcher	
Signature	
Date*	

*To be signed and dated in the presence of the participant.

This project was approved by the University of Leeds ethical protocols (Ethics Reference **LTSEE-026**).

Phase 3 of data collection



July 2015 Strategic planning for low carbon heat and the role of district heating

I would like to thank you for consenting to participate in my PhD research project.

Who I am

Ruth Bush is a PhD student in the Doctoral Training Centre for Low Carbon Technologies, based in the Energy Research Institute at the University of Leeds.

What the research is about

This research aims to explore actions currently taking place at both the local and national level to enable district heating to play a larger part in the UK energy system. Approximately 20 semi-structured interviews with professional stakeholders involved in influencing heat policy in Scotland and England at the local and national level will be undertaken.

Your answers will be recorded and kept in an anonymised and secure format. The findings of this research will be published with my PhD thesis. I may also report the research findings in academic journals and conference papers. If I quote anything you say to me in this interview, I will do so in an anonymised format, specifying only the type of organisation to which you belong. If there is anything that you would not wish me to communicate in any form following this interview, please state this clearly, and I will ensure this remains entirely confidential.

If you have questions, feel free to ask me now or at a later date. You can contact me by email: Ruth Bush: r.e.bush11@leeds.ac.uk.

Statement of Consent

I hereby consent both to take part in this research and to record the interview.

Signature _____ Date _____

Your Name (printed) _____

This consent form will be kept by the researcher until the end of the project, and was approved by the ethical review panel according to the University ethical protocols (Ethics reference **LTSEE-028**) on the 6th February 2015.

University of Leeds | Energy Research Institute and DTC for Low Carbon Technologies 1 of 1

Appendix C Interview questions – Phase 1 data collection

Interview questions – Phase 1 data collection

Background:

- Consent
- Aims of project

Visions and approaches to development

- Tell us about your role.
- How does district heating feature within your organisation's strategic outlook?
- To date, what DH projects have you been involved in developing?
    - Who led/facilitated these projects?
    - What was your involvement?
    - How were these financed?
    - Who else is involved?
- Are you considering any district heating projects at the moment?
- What partners do you work with when you develop DH projects?
    - How are links made with stakeholders who own key properties and heat loads?
    - What are the motivations / concerns of these people for being involved in DH projects?
- What resources (e.g. staff, tools, time) do you have available for development of district heating projects?
    - Are they seen as a priority for the organisation?
- How does / would financing of DH projects (or other high investment projects) happen?
- What criteria do you consider within the decision-making process for choosing a project?
    - Minimising capital investment
    - Carbon reduction targets

    - Timeframes
- What are the barriers that you face to developing district heating?

Heat mapping tools to support project development

- What criteria do you look for when identifying locations suitable for a district heating project technically?

(For those seeking funding support)

- What data is used to decide eligibility for the funding (e.g. ECO)?
- Do you have any experience of using tools to support decisions on district heating / energy efficiency improvements?
    - What was useful?
    - What was felt to be lacking?
    - Do they support targeting for fuel poverty alleviation?
    - Do they focus on households eligible for ECO / social housing or the city as a whole?
- If we were to develop an easy and quick-to-use mapping tool aimed at local authorities that would be able to highlight areas with potential for district heating development and high fuel poverty levels, would this be useful?
    - What information would you want it to be able to deliver?
    - What features would be useful from such a tool? (e.g. number of fuel poor households that could be supported, average fuel bill reduction as a result of a not-for-profit scheme).

Thanks! Is there anything we haven't covered that you feel is important?

Follow-up:

- Would you like to be kept informed about the outcomes of this project?

Appendix D Semi-structured interview questions used to interview local authority actors in relation to heat mapping tools (Chapter 6)

Introduction:

- Tell us about your role.

Motivations

- What are the main motivations of your local authority for facilitating DH project development?

Modelling tools

- What are your thoughts on use of modelling tools to support planning of district heating including identification of suitable sites and/or feasibility studies?
    - Is the use of modelling tools effective?
    - What other support is needed for local authorities
- What do you feel is lacking from existing modelling tools?
    - Are there any data restrictions that you would like to see improved?
- Do modelling tools play a role in enabling project financing?

Decision making criteria

- What criteria are considered within the decision-making process for projects? (e.g. Minimising capital investment, Carbon reduction targets, Timeframes, Cost effectiveness of measure, Social criteria, What properties are targeted? Why certain areas?)
    - Which criteria are the most influential?
- How are assessment criteria determined?
    - Politically?
    - Nationally? / Individually by each local authority?

Resources

- What resources (e.g. staff, tools, time) are available for development of district heating projects in local authorities across Scotland?
    - Are they seen as a priority?

Existing projects

- Where has activity with district heating taken place to date in your local authority area?
    - Who led / facilitated these projects?
    - Who else was involved? (Partners? Funders?)
    - How were they financed?
    - Have they reduced energy bills for residents?

Appendix E Leeds Heat Planning Tool method

Method for selecting relevant indicators

The interview data was analysed to identify decision criteria used by actors when at the planning stages of a DH project. The identified indicators were further validated with notes from discussions at a relevant stakeholder workshop where indicators were discussed explicitly (p.4, Vanguards Network, 2013). The indicators were then categorised into three areas: techno-economic, governance and social indicators.

Data selection

Data sets were selected to represent these indicators from official census data and UK Government statistics. The lowest available spatial resolution of 'census output area' (approximately 125 households per area) was used, with the exception of fuel poverty data and indices of multiple deprivation that were only available at lower super output area (LSOA). This offered sufficient resolution for early stage district heating planning to identify general areas of potential. The data sets used within the Leeds Heat Planning Tool are detailed and referenced in Table 13. Where publically available data sets did not exist to represent a key indicator, the tool was designed so that tool users could easily represent key factors within their area with minimal data collection work.

Notable areas where data was not publically available consisted of:

- Potential heat sources (other than existing CHP plants),
- Large heat demands such as hospitals or swimming pools.

Gaining access to detailed versions of relevant data sets can be difficult and time consuming. However, local authorities often already knew general information about the existence of these resources, including their location. At the early stages of project prioritisation and stakeholder engagement, this work suggests that detailed figures about available heat supply and heat demand are not required to inform the process. The analysis within part 1 of this chapter has shown that at the early stages of the development process, building understanding and trust with stakeholders about the potential of a project is important. The tool is therefore

designed to allow users to input postcodes for these key features and this is reflected within the score for the relevant output area.

Table 13: Detailed data information used within the Leeds Heat Planning Tool

	Data category	Data source	Data resolution
Techno-economic	Existing CHP plants	DECC CHP database (CHPQA Programme, 2012)	Postcode
	Heat sources	User-added	Postcode
	Large heat demands	User-added	Postcode
	Household density (number of households per km^2)	Area of LSOA calculated using ArcGIS. Density calculated using the 'number of households' from the census divided the area of the OA to give the number of houses per km2 (Census Data, 2011a)	Super output area
	Flats, maisonettes or apartments (number)	Census data - accommodation type by OA level (Census Data, 2011a)	Super output area
	Terraced households (number)	Census data - accommodation type by OA level (Census Data, 2011a)	Super output area
Governance	Social rented households (number)	Census data - accommodation type by OA level (Census Data, 2011a)	Super output area
	Council owned social rented households (number)	Census data - accommodation type by OA level (Census Data, 2011a)	Super output area
Social	No central heating system (number of households)	Census data at OA level of central heating (Census Data, 2011b)	Super output area
	No gas central heating (number of households)	Census data at OA level of central heating (Census Data, 2011b)	Super output area
	Oil central heating (number of households)	Census data at OA level of central heating (Census Data, 2011b)	Super output area
	Solid fuel central heating (e.g. wood, coal) (number of households)	Census data at OA level of central heating (Census Data, 2011b)	Super output area
	Electric heating (including storage heaters) (number of households)	Census data at LSOA level of central heating (Census Data, 2011b)	Super output area
	Off-gas households (Centre for Sustainable Energy)	CSE website (Xoserve, 2013)	Super output area
	Fuel Poverty households 10% measure (number of households)	DECC (DECC, 2013a)	Lower super output area
	Fuel Poverty households LIHC (number)	DECC (DECC, 2013b)	Lower super output area
	Index of Multiple Deprivation	Department for Communities and Local Government, 2010 data (Department for Communities and Local Government, 2011)	Lower super output area

		Welsh Government 2011 data (Welsh Government, 2011)	
	Eligible for CSCO funding (ECO)	DECC – Sourced from Centre for Sustainable Energy website (DECC, 2012a)	Super output area

Data references

CHPQA PROGRAMME 2012. CHP database. Published by: Department of Energy and Climate Change.

CENSUS DATA. 2011a. Accommodation type - Households, 2011 [Online]. Available: http://www.nomisweb.co.uk/census/2011/qs402ew [Accessed 28.03.2014 2014].

CENSUS DATA. 2011b. Central Heating Type, 2011 [Online]. Nomis. Available: http://www.nomisweb.co.uk/census/2011/qs415ew [Accessed 28.03.2014 2014].

DECC 2013a. Fuel poverty 2011 detailed tables - 10 per cent measure.

DECC 2013b. Fuel poverty 2011 detailed tables - Low income high costs indicator.

DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT. 2011. Statistics - English indices of deprivation 2010 [Online]. Available: https://www.gov.uk/government/publications/english-indices-of-deprivation-2010 [Accessed 28.03.2014 2014].

WELSH GOVERNMENT. 2011. Statistics - Welsh Index of Multiple Deprivation (WIMD) [Online]. Available: http://wales.gov.uk/statistics-and-research/welsh-index-multiple-deprivation/?lang=en#/statistics-and-research/welsh-index-multiple-deprivation/?lang=en [Accessed 28.03.2014 2014].

XOSERVE. 2013. GB postcodes off the mains gas grid [Online]. Centre for Sustainable Energy,. Available: http://www.cse.org.uk/resources/open-data/off-gas-postcodes [Accessed 28.03.2014 2014].

DECC. 2012a. Energy Company Obligation - Carbon Saving Community Obligation: Rural and Low Income Areas [Online]. Available:

http://www.cse.org.uk/resources/open-data/energy-company-obligation-data- [Accessed 28.03.2014 2014].

Representing heat demand

In the absence of a data source specifically for heat demand in the UK, building density was used as a proxy for heat density. This was particularly important in the domestic sector when considering potential for fuel poverty alleviation since households in fuel poverty often under-heated their homes. A proxy based upon real energy consumption of gas and electricity could therefore under-represent the potential demand for heat in a given area with a scenario of more affordable heat prices such as a not-for-profit DH scheme.

Data availability was still problematic when using a proxy of building density for heat demand since there were no data sets available for non-domestic buildings. The tool therefore relies at present on input of key non-domestic heat demands by the user.

Aligning lower super output area data to super output area resolution

Scoring within the tool was assigned at census output area resolution. However, fuel poverty data and indices of multiple deprivation data was only available at lower super output area (LSOA). A score was generated for each census output area based upon the lower super output area to which it belonged. Figure 15 illustrates how scoring for these data sets were assigned to each census area, using the example of fuel poverty data. When a lower super output area had a high level of fuel poverty, all the census areas contained within that lower super output area would receive a score to indicate a high level of fuel poverty.

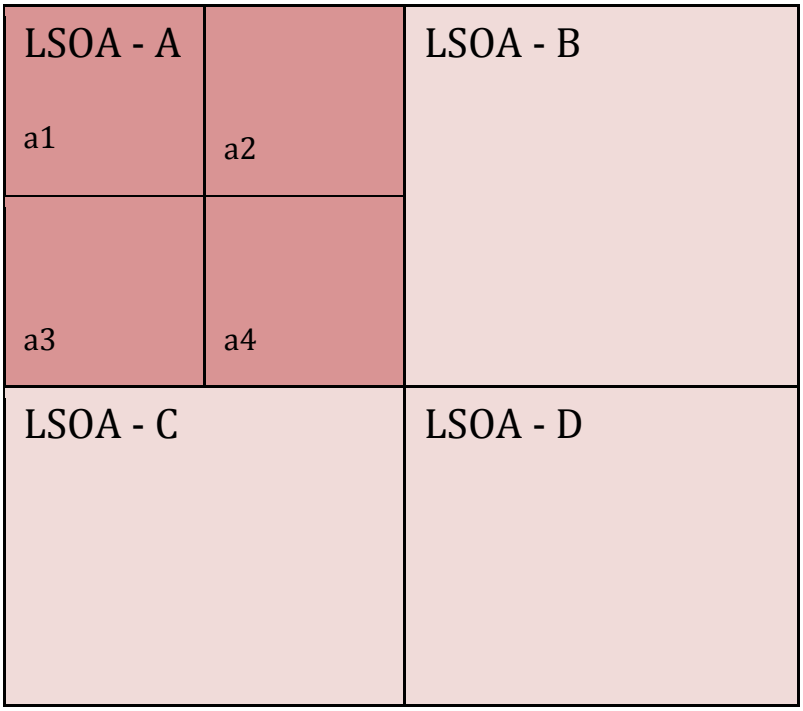


Figure 14: Description of the process for assigning a score to each census output area for data only available at lower super output area (LSAO) resolution – using the example of fuel poverty data.

Scoring census output areas

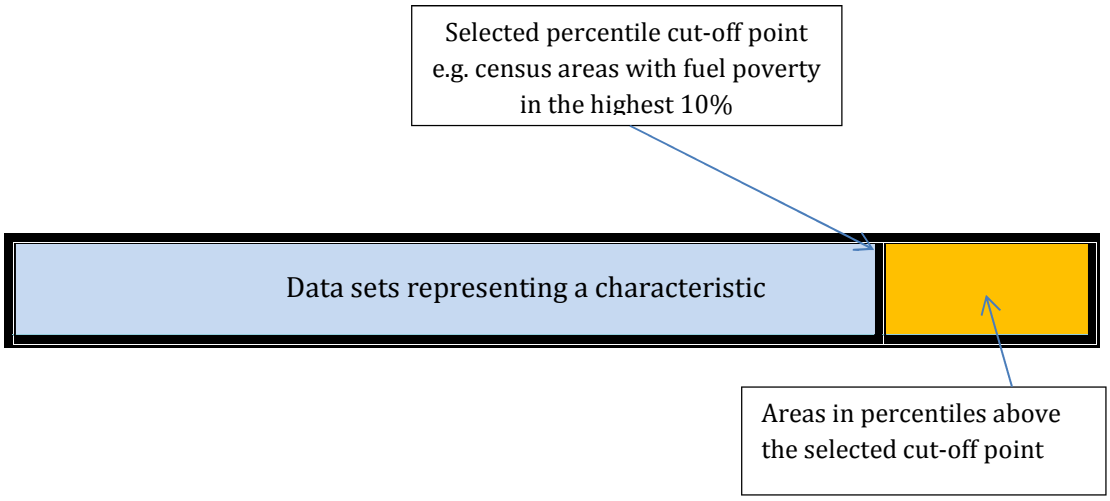


Figure 15: The percentile cut-off point for data sets

Characteristics that are binary in their nature (i.e. where the characteristic is either present in an area or it is not) are assigned a score if the characteristic is present. For example, the presence of an existing CHP plant and large heat loads such as a

hospital or swimming pool are binary characteristics. No percentile cut-off point is required for these characteristics.

For characteristics represented by a continuous data set, a percentile cut-off point is used to determine when an area exhibits a 'high' level of a characteristic (Figure 15). The percentile cut-off is selected by the user, and is calculated using the data sets within the local authority area in question (as opposed to data sets across England and Wales). An increased score is assigned to the census areas with characteristics in these top percentiles.

Weighting of characteristics

The can weight each characteristic by rating it between 1 and 5. This enables the user to explore and compare the impact of different weightings; for example, where social factors are weighted very heavily compared to techno-economic factors.

The user can enable and disable characteristics according to their preferences. The weighted scores are assigned as a percentage of the activated characteristics to ensure scenarios are comparable. The scores received for each activated characteristic are then added up to give the total score for each area. This calculation is described algebraically by the following equation:

$$S_i = \sum_j \left(\frac{W_j}{\sum W} * X_{ij}\right)$$

Where:

S_i is the total score attributed to census output area i in the selected local authority;

W_j is the individual weighting given to the activated characteristics j;

X_{ij} = 1 when the activated characteristic j is above the percentile cut-off point in the given area, i. Otherwise X_{ij} = 0.

Appendix F Scenario settings used in the application of the Leeds Heat Planning Tool

Table 14: Variables selected for two scenarios of the case study city of Leeds (presented in section 6.3.3)

		Scenario 1 – Techno-economic criteria				Scenario 2 – Social criteria added in			
Categories		Activate?	Percentile cut-off point?	Individual weighting (1 : 5)	Overall weighting %	Activate?	Percentile cut-off point?	Individual weighting (1 : 5)	Overall weighting %
Techno-economic	Existing CHP plants	Yes	n/a	5	100%	Yes	n/a	2	44%
	Heat sources	Yes	n/a	5		Yes	n/a	2	
	Large heat demands	Yes	n/a	5		Yes	n/a	2	
	Household density (#households per km^2)	Yes	0.9	3		Yes	0.9	5	
	Flats, maisonettes or apartments (number)	No	0.9	n/a		Yes	0.9	2	
	Terraced households (number)	No	0.9	n/a		Yes	0.9	2	

		Scenario 1 – Techno-economic criteria				Scenario 2 – Social criteria added in			
Categories		Activate?	Percentile cut-off point?	Individual weighting (1 : 5)	Overall weighting %	Activate?	Percentile cut-off point?	Individual weighting (1 : 5)	Overall weighting %
Governance	Social rented households (number)	No	0.9	n/a	0%	Yes	0.9	3	9%
	Council owned social rented households (number)	No	0.9	n/a		No	0.9	n/a	
Social	No central heating system (number households)	No	0.9	n/a	0%	No	0.9	n/a	47%
	No gas central heating (number of households)	No	0.9	n/a		Yes	0.9	5	
	Oil central heating (number of households	No	0.9	n/a		No	0.9	n/a	
	Solid fuel central heating (e.g. wood, coal) (number of households)	No	0.9	n/a		No	0.9	n/a	
	Electric heating (including storage heaters) (number of households)	No	0.9	n/a		No	0.9	n/a	

		Scenario 1 – Techno-economic criteria				Scenario 2 – Social criteria added in			
Categories		Activate?	Percentile cut-off point?	Individual weighting (1 : 5)	Overall weighting %	Activate?	Percentile cut-off point?	Individual weighting (1 : 5)	Overall weighting %
Social (continued)	Off-gas households (Centre for Sustainable Energy)	No	0.9	n/a		No	0.9	n/a	
	Fuel Poverty households 10% measure (number of households)	No	0.8	n/a		No	0.8	n/a	
	Fuel Poverty households LIHC (number)	No	0.8	n/a		Yes	0.8	4	
	Index of Multiple Deprivation	No	0.8	n/a		Yes	0.8	2	
	Eligible for CSCO funding (ECO)	No	0.8	n/a		Yes	0.8	5	

Appendix G Interview questions used for semi-structured interviews with selected actors

Context / Background

1. Tell me about your organization and role.
    - What type of activities do you do with specific DH projects?
    - How long have you been in your role?
2. How has your role / organisation changed over time in relation to DH?
    - Have you worked on developing schemes previously? Were they successful?

Market

3. What are your key drivers for working on DH at present?
    - How has this changed over time? Why?
4. What are the key barriers for working on DH at present?
    - How has this changed over time? Why?
5. Has your business model for DH projects changed over time?
    - How? Why?

Local institutional / actor networks and influence

6. Who do you work with at the local level to get projects delivered?
    - How has this changed over time?
    - Why?
7. Do you spend time sharing your experiences with other organisations to enable more DH schemes?
        - What about learning from others? Has this process got easier / harder over time?
        - Why? How has this changed over time?
8. Do you have a strategic approach to heat / DH? Or are you developing one?
    - Why? What should they contain?
    - What are your objectives for the strategy?

Users / social / culture

9. Have consumer perceptions had an influence over your approach to DH development?
    - How have they changed over recent years? (Commercial, industrial, public sector, domestic).
    - How? Why?

Technologies and infrastructures

10. Do you think there are more technological changes required to enable wider uptake of DH? Why?
    - Has it changed in recent years? How?
    - What has driven this change?
11. Has delivering DH got any easier during your time working on the issue?

Policy

12. How has the national policy landscape influenced your activity in DH?
    - Has it been useful in stakeholder engagement?
13. Does the current policy regime in the UK suit certain types of DH more than others?
    - How has this changed?
    - Does your current business model suit the policy regime?
14. How do you work to influence the policy direction on DH and heat in the UK?
    - What are you advocating?
    - Has this changed over time? How? Why?
    - Do you work with partners? Trade Associations?
    - Influence from organisations internationally? Why?
15. What's the stability of the current policy situation in your opinion? Why? How might it change?

Perceived tensions / risks in the current regime

16. What do you see as the challenges or risks facing the DH sector in the next 10 – 20 years?
    - How are you dealing with these risks?