



The 15th International Symposium on District Heating and Cooling

The role of intermediaries in the transition to district heating

R. E. Bush¹ and C. S. E. Bale^{2,3*}

¹ *Low Carbon Technologies Doctoral Training Centre, School of Chemical and Process Engineering, University of Leeds, UK*

² *School of Chemical and Process Engineering, University of Leeds, UK*

³ *School of Earth and Environment, University of Leeds, UK*

Abstract

For those countries, such as the UK, in which district heating and cooling has previously played little role in the energy system, the technology often struggles to break through the numerous and complex barriers to its introduction in the context of liberalised energy markets and competition with incumbent technologies such as natural gas networks. Progress is often slow and best practice is yet to be established.

‘Intermediaries’ are actors who facilitate knowledge sharing and build actor networks to enable the introduction of new technologies. This paper uses a case study of the UK to explore where and how the activities of these intermediary actors are currently supporting district heating development.

An innovative method called a ‘decision theatre’ was used to collect empirical evidence from a range of local stakeholders involved in district heating projects. This method, which took place in the format of a group workshop, enables understanding of the interactions between stakeholders through each stage of the district heating development process.

Lessons are drawn from this case study with regard to how intermediary activities can support the development of district heating in areas with little previous history of such systems. Three geographical scales of intermediary activity are identified (local, regional and national) as having different roles in enabling delivery of new district heating projects. Interactions between the three scales and how their roles might change as the sector develops are explored. The paper will highlight implications of the study for policymakers. In particular, a role is identified for intermediaries in creating a supportive institutional and policy environment that can enable development of large-scale, strategic networks.

© 2017 The Authors. Published by Elsevier Ltd.

Peer-review under responsibility of the Scientific Committee of The 15th International Symposium on District Heating and Cooling.

Keywords: *Intermediaries; Policy; Strategic planning;*

* Corresponding author. Tel.: +44 (0)113 343 8250

E-mail address: C.S.E.Bale@leeds.ac.uk

1. Introduction

A realisation about the scale of the challenge of decarbonising the heat sector has brought about an increased interest in the potential of district heating (DH) [1]. Introducing DH in countries where the technology has not previously been used brings with it a set of non-technical challenges including developing an institutional infrastructure, market and business models that unlock the technology for deployment. In this paper we refer to these countries as ‘learning countries’.

Local municipalities often seek to play a role in overcoming these non-technical barriers and enabling delivery of new schemes [2]. However, in the context of a low penetration of existing networks, they can be working with little previous experience or knowledge of what is required. The process of learning and knowledge exchange is therefore important for unlocking DH potential.

This paper will focus on the concept of ‘intermediaries’. These are actors that facilitate connections between institutions involved in delivering new innovations to enable exchange of knowledge, development of skills and standards, and development of relationships between actors to support the process of innovation. Gaining an understanding of how intermediary activities are currently taking place, and where they could be improved, is critical for policy makers in learning countries that are looking to strengthen capacity of local actors to deliver DH.

A case study from the UK is used as an example of a DH learning country. It is a country with a highly centralised energy system, a liberalised energy market, and high penetration of natural gas networks for heat supply to buildings. The heat demand currently delivered by DH is only 2% [3]. This paper will analyse data from a decision theatre workshop involving a range of local stakeholders involved in DH development at the local level. It will consider where intermediary activities are taking place; who is delivering the activities; and how they could be developed further to enable successful development of more DH projects in the UK.

2. Theoretical basis for analysis

Socio-technical theory forms the theoretical basis for analysis. The theory seeks to recognise the influence of the existing system as new technologies and innovations are introduced. It considers incumbent technologies, institutional and market set ups, policy regimes and social practices [4].

The theory considers technology innovations, such as the process of delivering DH in learning countries, to take place within ‘**niches**’. ‘Niches’ are used to describe the idea of protected spaces where technological innovations are able to develop and learn before being embedded into the wider regime [5]. Protection within the niche can come in many forms; from financial subsidies or tax breaks, to skills development programmes or transferring of decision-making powers. In practice, technological innovations might happen in multiple niches across a country, and the experiences at each local level can be collected and shared together to contribute to innovation development across the niche as a whole [6, 7].

In this work we are considering the process of DH development in learning countries as taking place in niches. Although DH is a well-established and proven technology in many countries such as Denmark, Sweden and Finland, in ‘learning countries’ such as the UK it requires non-technical innovations to take place to enable its deployment. The term DH niche will be used to describe the delivery of a new DH project in a region of low or no deployment of DH. It could take the form of an extension of an existing scheme, but is most likely to be the delivery of a stand-alone network.

2.1. Intermediaries

In socio-technical theory intermediaries can be defined as actors that facilitate exchange of knowledge, or use their own expertise to facilitate creation of niches and delivery of technologies. They are actors that span individual niches, networks and learning boundaries and they can undertake work at multiple levels; using their expertise to add value to project delivery within the niche and aggregating and sharing learning between niche spaces of activity [7-9]. Table 1 gives some examples of the types of activities intermediaries undertake. For a more comprehensive list of specific activities observed in studies to date, see Kivimaa [9].

Table 1: Examples of four types of intermediary activities as reviewed by ¹Kivimaa [9] and ²Hargreaves et al [7]

Articulation of values and visions for the future ¹	Building of social networks ¹
Strategy development	Aligning interests
Demonstration of technology benefits	Creation and facilitation of new networks for both learning & project delivery
Acceleration of the application and commercialisation of new technologies	Finding funding sources to support activities.
Learning processes and exploration at multiple dimensions ¹	Brokering and coordinating partnerships beyond the niche ²
Knowledge gathering, processing & combination	Accreditation and setting of standards
Communication and dissemination of knowledge	Consultation on policies
Advice and support	Policy communication and implementation

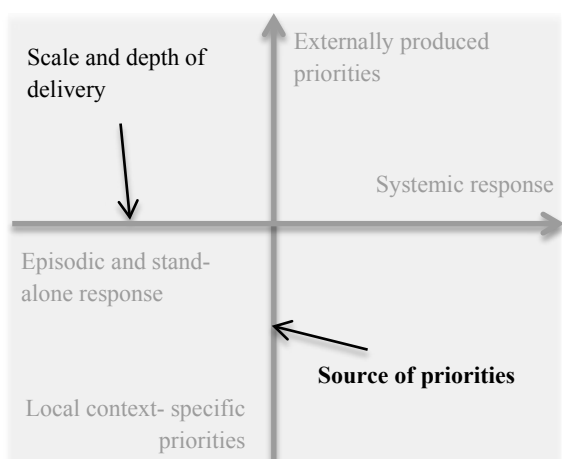


Figure 1: Modes of urban energy intermediation conceptualised by [10]. The x-axis shows the scale and depth of delivery of intermediary activities, and the y-axis shows the scale at which the priorities for intermediary activities are defined.

Further to the practical activities that intermediaries undertake to assist in niche creation, Hodson, et al. [10] consider ‘modes’ of intermediary actors and how their scale and capacity can impact on their long-term effectiveness for enabling technology innovations to develop and transition beyond niche activities and become part of the wider regime. Figure 1 shows the two dimensions that Hodson et al [10] use to define the modes of intermediary delivery: (1) the scale and depth at which activities are embedded into institutional practice, either taking place as a stand-alone response or via an activity that is embedded within the long-term functioning of existing organisations; (2) the scale at which the priorities of intermediaries are defined, these could come from the local context of the niche, right through to a top-down national policy directive.

We apply this framework to the case study to consider the intermediary activities taking place to support DH development, and also the modes that these activities are being delivered through.

2.2. The context of DH in the UK

The UK is a challenging country for DH deployment with extensive natural gas network coverage in its towns and cities. It has a highly centralised and liberalised energy system with little involvement of local or regional level actors to date [11]. Nevertheless, the publication of the UK Strategic Heat Framework [3] and action plan [12] recognised that DH would play an important role amongst the mix of technologies needed to meet future low carbon heating demand. It also recognised local authorities as having a critical role for enabling DH delivery.

The Heat Network Delivery Unit (HNDU) was formed within the Government’s Department for Energy and Climate Change (DECC) in summer 2013 to support local authorities in England and Wales in taking on this new role. It 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 [13]. The existence of HNDU appears to have ramped up the numbers of local authority officers working on DH, but as yet most of these projects have not reached the delivery stage and DH development continues to take place within niche spaces rather than becoming part of the mainstream practice for most municipalities.

2.3. Research questions

This work seeks to answer the following research questions:

1. Are intermediary activities taking place within the DH development process in the UK? Which actors are delivering these activities?
2. Where are they adding value to support the development of projects?
3. How could intermediary activity be strengthened for DH niche creation?

3. Decision theatre methodology

Data was collected for this chapter through an adaptation of a decision theatre research process; a method originally developed by Arizona State University that uses data visualisation, modelling and simulation to engage multiple stakeholders in a complex group decision process [14–16]. Use of a decision theatre research process aimed to capture rich and detailed data about the interactions and relationships between stakeholders during the process of decision making – a particularly important aspect in DH development where cooperation between local stakeholders in charge of large heat demand anchor loads and heat supply sources are crucial to enabling the viability of a project. Furthermore, this method is 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 [14].

The decision theatre research process was adapted for the purposes of this study to focus less on the use of detailed modelling that was emphasized by previous applications of the method. Instead, a fictional scenario was created and simulated through simple heat maps, qualitative information about key actors in the scenario, and basic information about the outcome of a feasibility study. This adaptation was done 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 2. 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 presented with the information that the given project was technically and financially viable to be delivered, given the involvement of key anchor loads and heat supply sources. Participant discussions were facilitated around the key points listed in Figure 2 to explore different actor’s objectives and challenges at different stages of the process, including:

- When and where actors turned to get 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.

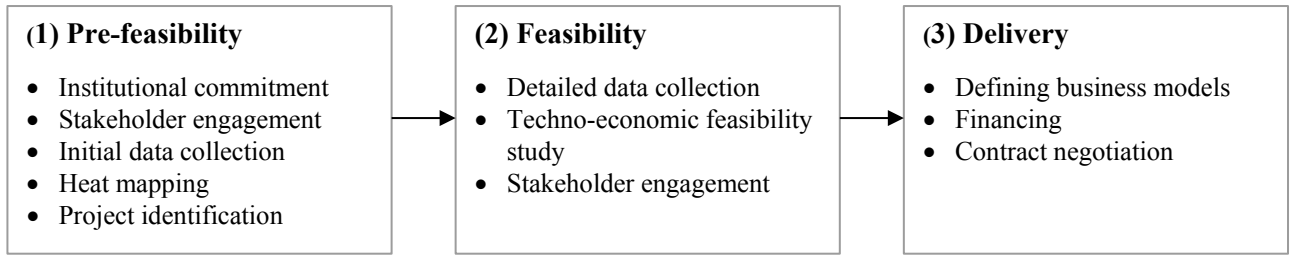


Figure 2: Outline of the three stages of the DH development process considered within the decision theatre workshop. Example activities from each stage are given. Although this diagram suggests a linear process, iterations between each of the activities often take place over time as contexts and stakeholders 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 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 Table 1, to identify how and where intermediary activities were taking place throughout the development process stages.

A range of 10 stakeholders involved in local-level activities for establishing new DH networks within the UK were invited to participate and collaborate in the daylong decision theatre workshop held in Newcastle, UK during October 2014 (8 stakeholders 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.

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.

4. Results

Analysis of the decision theatre data highlighted the central role of local authorities within delivery of DH niche processes, either undertaking intermediary activities themselves or being supported by the intermediary activities of others. Activities took place at three geographical scales of engagement: locally (primarily delivered by the local authority); regionally (several local authorities working together through a local enterprise partnership); and nationally (via institutions such as trade associations, community group networks, or government programmes). Figure 3 shows examples of the range of local stakeholders involved with DH delivery and the connections where local, regional and national actors were undertaking intermediary activity.

At the **local level**, the local authority sustainability or energy team performed intermediary activities 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. 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[†], the Vanguard Network[‡] 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.

4.1. Evolution of intermediary roles as the niche processes develop

Table 2 gives details of the observed intermediary roles undertaken by the actors at each scale and how these vary throughout the stages of the DH development process. Most of the actors within the decision theatre are currently at stages (1) and (2) of the delivery process, establishing conditions for successful delivery of an initial project.

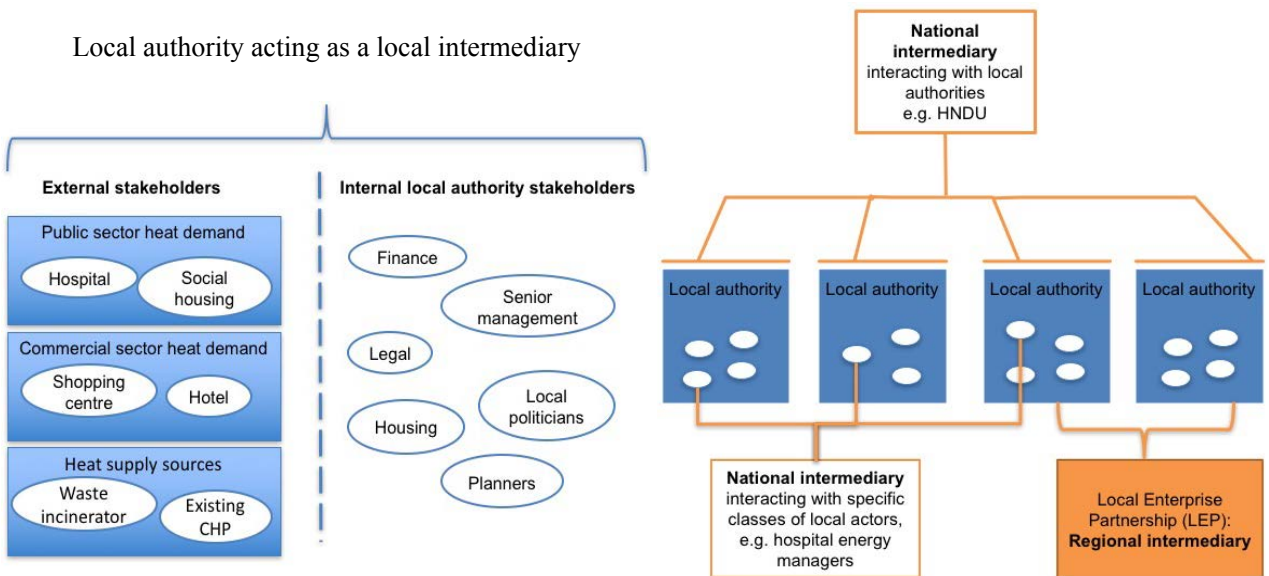


Figure 3: Illustration of the local, regional and national intermediary relationships where engagement and networks currently exist for enabling district heating development in the UK. There are two types of national intermediaries represented: (1) that works with local authorities and (2) that works with other specific types of actors such as hospital or university energy managers.

[†]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.

[‡]The Vanguard 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.

This analysis of the DH development process shows the important role that intermediaries can play in delivering niche processes. The multiple scales of activity offer distinct benefits, from close connection to project delivery and alignment of interests at the local level, to sharing knowledge and pooling resource at the regional and national levels. As projects and niches develop, the role of intermediaries also develops and changes to fulfill new functions.

Table 2: Intermediary activities undertaken at the local authority, regional local enterprise partnership (LEP) and national scale (HNDU and other networks) at each stage of the DH development process.

	Intermediary activity	Who?	Comments
(1) Pre-feasibility	Increasing awareness of DH: In the context of very little existing DH, it is rare that local stakeholders had experience of DH development. Work needed to be carried out to introduce people to the technology, both internally and externally to a local authority. 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.	Local authority	✓ Activities focused both internally with local authority stakeholders such as its senior management team, politicians, and finance managers, as well as externally with local stakeholders who might need to be involved to provide heat supply or large heat demand anchors.
		LEP (regional)	✓
		National body	
	Demonstrating the value of DH: The aims and objectives of each local actor for engaging with DH varied between individual stakeholders. Local authorities and LEPs spent time understanding the drivers and benefits sought by each stakeholder and worked to demonstrate the value that DH has to offer to each one using case studies and site visits to existing schemes from within the UK and abroad.	Local authority	✓ For regions where the LEP was taking an active role in facilitating DH, 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 due to lack of resources.
		LEP (regional)	✓
		National body	✓
(2) Feasibility	Providing an evidence base for feasibility: This involved gathering detailed data to feed into a feasibility study; obtaining funding for a study to be carried out (primarily through HNDU funding, or alternatively by direct funding from the local authority or LEP); and the local authority or LEP commissioning consultants to undertake the study.	Local authority	✓ 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.
		LEP (regional)	✓
		National body	✓
	Overcoming a high perception 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 an important tool for achieving this. Participants talked of a "responsibility" on successful projects to share more details with others.	Local authority	✓ HNDU played an important role consistently supporting projects right through the development process, as well as connecting and sharing information between local authorities. However, Participants expressed a desire for more opportunities to connect key peer groups, such as university or hospital finance directors or planning officers.
		LEP (regional)	✓
		National body	✓
(3) Delivery	Use of the public sector estate to reduce risks: Local authorities aimed to offer an anchor load of long-term heat demand through public sector estate to increase certainty around the long-term business case for a scheme. They also considered using public sector-only access to low-interest loans to cover the upfront capital costs of schemes, therefore requiring lower rates of returns than commercial rates would require.	Local authority	✓ Emphasis transferred away from the LEP as a lead intermediary at the deliver stage 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.
		LEP (regional)	
		National body	
	Developing ownership models for schemes was a key point of discussion that lacked a clear vision for many actors. Local authorities were keen to maintain an element of ownership within schemes in the hope of leveraging greater benefits for the area (e.g. maintaining low heat costs for fuel poverty reduction, or generating income through scheme profits).	Local authority	✓ Lack of commercial 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 distrust of private sector actors.
		LEP (regional)	✓
		National body	✓

5. Discussion

Analysis of this UK case study has shown the extensive role that intermediaries can play in niche creation throughout DH development. The multiple scales of activity offer distinct benefits, from close connection to project delivery at the local level, to sharing knowledge and pooling resource at the regional and national levels. The early stages of DH development for most areas in the UK means that most of the intermediary activities are focused at the first two stages of the development process at present, but over time this would be expected to evolve as DH becomes a more widely known and trusted option amongst local decision makers.

In this section, the two dimensions that define the modes of energy intermediaries set out by Hodson, et al. [10] are used to explore how the role of intermediary activities in niche creation could be strengthened for DH. In particular, we consider how intermediary activities and modes might transition DH development from a niche activity to becoming part of the mainstream energy regime.

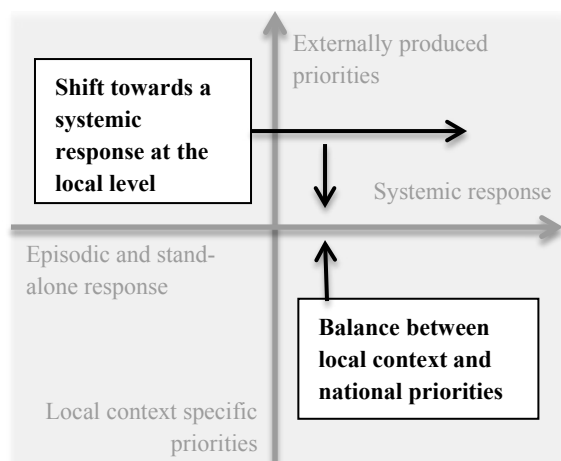


Figure 4: Analysis of the role of intermediaries for diffusion of DH niches into the mainstream energy regime

The activities of local authorities were of note when focusing on the ‘depth of activity’, represented on the x-axis of Figure 4, who were often seeking to deliver a systemic response through delivery of local heat strategies, planning policies and sometimes municipally owned energy service companies to facilitate strategic development and growth of DH for the long term. However, the lack of top-level strategic commitment and vision from within the local authority combined with the challenges of internal capacity and access to resource were creating a serious barrier for many of the stakeholders to achieve this.

These challenges at the local level were influenced by the national level, where there was a conspicuous lack of clear strategic steer to empower local authorities and LEPs in their role as DH intermediaries. Although national policy measures highlight local authorities as having a critical role in DH delivery [12], they do not yet support this with an explicit definition of

responsibilities, or sufficient resourcing and delegation of powers to enable local authorities to consistently commit to this role. The sector would benefit from further dialogue and greater clarity about what the responsibilities and powers of local authorities are in relation to DH, the extent to which they should use local authority and public sector estates to enable viability of schemes, and indeed, strive to retain ownership of new schemes.

Returning to Hodson, et al. [10] and considering the ‘scale at which priorities are defined’, represented on the y-axis of Figure 4, a tension highlighted in this work is the balance between local and national influence. In the context of a centralised energy system, energy policy priorities are traditionally driven at the national level. However, given that the local context is so important for DH and local authority motivations tend to adapt to this context, this local voice is an important influence over the successful implementation of national energy policies. Even at the regional scale of the LEP, the emphasis on local economic growth may mean that some of the social drivers such as fuel poverty reduction (often prioritised by local authorities) are potentially not fulfilled [17]. An increased role for local authorities as local energy intermediaries requires greater dialogue between local and national governments to ensure that local priorities and activities are integrated into the energy system and national decision making across the country. National and regional intermediary activities clearly have an important role to play in enabling this dialogue to take place.

DH development in the UK is still taking place in the context of niches with few projects successfully getting through to delivery and completion. However, even at this early stage it is apparent that a transition from niche activity to the mainstream would require both a shift towards a more systemic response, particularly at the local level, and also a greater balance and dialogue between nationally defined priorities and the voices from the local context.

6. Conclusion

This work has used the innovative methodology of a decision theatre to explore the role of intermediaries within the process of DH development in a liberalised, centralised energy system. The results illustrate the power of intermediaries in enabling niche creation for DH development.

In the UK case study explored here, intermediary activities delivered several critical functions that enabled successful delivery of DH. They increased understanding of the technology amongst local stakeholders who needed to engage with potential projects. They sought resources to buy-in specialist expertise to support inexperienced actors. They also worked to overcome perceptions of risk by sharing case studies of other projects to reassure decision makers, and committing public sector estate to projects to increase security of heat demand. Still, there was potential to strengthen their impact by increasing the capacity and resource of local actors and more consistent provision of national level activities.

Lessons from the case study presented here are applicable beyond the context of the UK. DH delivery benefited from intermediary activities taking place at multiple levels of the energy system; the local and regional level play a critical role in direct delivery of projects while the regional and national level enable sharing and pooling of experience and resources to support the local level. In particular, the local nature of DH requires empowerment of local level actors, but supported by long-term intermediary actors who can maintain dialogue between the national, regional and local levels and establish clarity over powers and responsibilities as local actors take on a new role in coordinating strategic delivery of DH.

Finally, use of the ‘modes of energy intermediaries’ framework has highlighted their potential of intermediary actors to support a transition beyond DH development in stand-alone niches towards becoming an integrated part of the energy system. Embedding intermediary activities systemically into the multiple levels of the energy system, particularly at the local level, offers the potential to establish the institutional infrastructure and consistent support needed to unlock the potential of DH in many countries.

Acknowledgements

The authors are grateful to all the participants that took part in the decision theatre workshop. Thanks to Dr Katy Roelich, Dr Jonathan Busch (Sustainability Research Institute, University of Leeds) and Claire Walsh (iBUILD project, Newcastle University) for their collaboration on delivery of the decision theatre workshop. Thanks also to Professor Paul Upham (now based at Leuphana University Lüneburg) for his helpful comments and advice on the theoretical basis of this paper.

This work was funded by the UK Engineering and Physical Sciences Research Council (EPSRC) through the University of Leeds Doctoral Training Centre in Low Carbon Technologies (Grant EP/G036608/1) and a fellowship for CSEB (Grant EP/K022288/1). Mark Powell was funded by the EPSRC programme, i-BUILD: Infrastructure BUiness models, valuation and Innovation for Local Delivery, (Grant EP/K012398/1)

References

- [1] D. Connolly, H. Lund, B. V. Mathiesen, S. Werner, B. Möller, U. Persson, *et al.*, "Heat Roadmap Europe: Combining district heating with heat savings to decarbonise the EU energy system," *Energy Policy*, vol. 65, pp. 475-489, 2// 2014.
- [2] A. Chittum and P. A. Østergaard, "How Danish communal heat planning empowers municipalities and benefits individual consumers," *Energy Policy*, vol. 74, pp. 465-474, 2014.
- [3] DECC, "The Future of Heating: A strategic framework for low carbon heat in the UK," Department of Energy and Climate Change, Ed., ed. London: DECC, 2012.
- [4] F. W. Geels, "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study," *Research Policy*, vol. 31, pp. 1257-1274, 12// 2002.
- [5] A. Smith and R. Raven, "What is protective space? Reconsidering niches in transitions to sustainability," *Research Policy*, vol. 41, pp. 1025-1036, 7// 2012.
- [6] F. Geels and R. Raven, "Non-linearity and expectations in niche-development trajectories: ups and downs in Dutch biogas development (1973–2003)," *Technology Analysis & Strategic Management*, vol. 18, pp. 375-392, 2006.
- [7] T. Hargreaves, S. Hielscher, G. Seyfang, and A. Smith, "Grassroots innovations in community energy: The role of intermediaries in niche development," *Global Environmental Change*, vol. 23, pp. 868-880, 2013.
- [8] F. Geels and J. J. Deuten, "Local and global dynamics in technological development: a socio-cognitive perspective on knowledge flows and lessons from reinforced concrete," *Science and Public Policy*, vol. 33, pp. 265-275, 2006.

- [9] P. Kivimaa, "Government-affiliated intermediary organisations as actors in system-level transitions," *Research Policy*, 2014.
- [10] M. Hodson, S. Marvin, and H. Bulkeley, "The Intermediary Organisation of Low Carbon Cities: A Comparative Analysis of Transitions in Greater London and Greater Manchester," *Urban Studies*, vol. 50, pp. 1403-1422, May 1, 2013 2013.
- [11] D. Hawkey and J. Webb, "District Energy Development in Liberalised Markets: situating UK heat network development in comparison with Dutch and Norwegian case studies," *Technology Analysis & Strategic Management*, pp. 1-14, 2014.
- [12] DECC, "The Future of Heating: Meeting the Challenge," ed. London, UK: Department of Energy and Climate Change, 2013.
- [13] DECC, "Overview of grant funding and guidance available to local authorities developing heat networks," Heat Network Delivery Unit, London2014.
- [14] C. L. Walsh, S. Glendinning, R. J. Dawson, K. England, M. Martin, C. L. Watkins, et al., "Collaborative platform to facilitate engineering decision-making," *Proceedings of the ICE-Engineering Sustainability*, vol. 166, pp. 98-107, 2013.
- [15] C. Bale, R. Bush, K. Roelich, J. Busch, and M. Powell, "Application of a decision theatre concept to the development of an agent-based model," in *Conference on Policy Modelling in Practice*, Centre for Research in Social Simulation, London, 2014.
- [16] D. D. White, A. Wutich, K. L. Larson, P. Gober, T. Lant, and C. Senneville, "Credibility, salience, and legitimacy of boundary objects: water managers' assessment of a simulation model in an immersive decision theater," *Science and Public Policy*, vol. 37, p. 219, 2010.
- [17] R. Bush, C. Bale, and P. Taylor, "Spatial mapping tools for district heating (DH): helping local authorities tackle fuel poverty," Report for Cheshire Lehamn Fund, Leeds2014.