



**UNIVERSITY OF LEEDS**

This is a repository copy of *Realising the social benefits of district heating through strategic planning*.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/81735/>

Version: Published Version

---

**Proceedings Paper:**

Bush, RE and Bale, CSE (2014) Realising the social benefits of district heating through strategic planning. In: UNSPECIFIED 14th International Symposium on District Heating and Cooling, 08-09 Sep 2014, Stockholm, Sweden. .

---

**Reuse**

Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

**Takedown**

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing [eprints@whiterose.ac.uk](mailto:eprints@whiterose.ac.uk) including the URL of the record and the reason for the withdrawal request.



[eprints@whiterose.ac.uk](mailto:eprints@whiterose.ac.uk)  
<https://eprints.whiterose.ac.uk/>

## **REALISING THE SOCIAL BENEFITS OF DISTRICT HEATING THROUGH STRATEGIC PLANNING**

*R. E. Bush<sup>1,\*</sup> and C.S.E. Bale<sup>2</sup>*

<sup>1</sup> Doctoral Training Centre in Low Carbon Technologies, University of Leeds

<sup>2</sup> Centre for Integrated Energy Research, University of Leeds

\*Corresponding author: r.e.bush11@leeds.ac.uk

### **ABSTRACT**

Affordability, low carbon and security are hailed as the three critical characteristics of our future energy system. In this respect, district heating offers towns and cities many attractive characteristics. In particular, under the right governance models, it can offer social benefits by lowering energy costs and alleviating fuel poverty.

This research uses the case study of the UK, a country where less than 2% of heat is delivered by district heating, but where levels of fuel poverty are a significant challenge. UK local authorities play an active role in the early planning stages of district heating and many are aiming to alleviate fuel poverty with these projects.

The results show that the full variety of actor motivations are not reflected within their decision criteria; although local authorities aspire to take a strategic planning role, this is not reflected in the mapping tools that they use in feasibility work. We propose a more flexible approach to mapping for strategic planning and consider its role in bringing forward DH schemes that reduce fuel poverty.

### **INTRODUCTION**

To date there has been limited implementation of district heating in the UK; only 2% of heat is supplied in this way [1]. However, the UK needs to radically transform its heating systems in the face of the energy trilemma: generating and supplying affordable, low-carbon, and secure heat.

In this paper we pay particular attention to the need to provide affordable heat in the domestic sector, and the issue of fuel poverty.

We consider the development of district heating (DH) in the UK, with particular focus on schemes that are led by local authorities. We examine the motivations of local authorities in developing DH schemes and the decision criteria they use in the pre-feasibility stage of the planning process (used to develop the business cases for a scheme and ensure political and stakeholder buy-in before detailed technical and economic assessment is carried out). We then consider whether the mapping and planning tools used by local authorities are fit for the purpose of meeting their stated objectives.

Policy context of DH in the UK

District heating became a focus of UK energy policy when it formed a critical role within the UK Heat Strategy 2012 for heating in cities [1]. One of the steps outlined in this strategy was increased support for local authorities to overcome the capacity and capability barriers and challenges to developing heat network projects. In the UK this signifies a step change in the way heat is delivered, moving from a centralised gas network model of provision to locally coordinated schemes. Local authorities, which have traditionally played little or no role within the energy system, are now being asked to offer a trustworthy source of advice, coordination of local stakeholders and, most critically, strategic energy planning [2]. This is interesting because local authorities have different motivations to traditional energy bodies and, therefore, the decision-making process (usually based on techno-economic) needs to emphasize alternative criteria. As a result, central government has put in place support mechanisms to enable local authorities to take on the role of a local strategic energy body using heat-mapping tools and training support.

The Heat Network Development Unit (HNDU) was formed by the Department of Energy and Climate Change in 2013 [3] to improve the capacity of local stakeholders to deliver DH, share best practice between projects, and fund feasibility and planning maps for towns and cities. The majority of available funding is for planning and feasibility studies with the aim of creating a business case to attract investors. Capital funding for projects is less plentiful and is restricted to EU funding or Energy Company Obligation (ECO) funding, which is imposed on energy companies in the UK to improve energy efficiency in low income, fuel-poor and hard-to-treat residential properties. ECO funding has most notably been used successfully to fund schemes connecting blocks of social housing flats, improving the comfort levels for residents within the flats and reducing fuel costs. However, due to the remit of HNDU and the lack of government capital funding for schemes, the majority of local authority activity has focused on mapping and feasibility studies with the idea of attracting external investors.

Affordable warmth

Providing affordable warmth to residents is a key challenge for local authorities in the UK and features

explicitly in many local authority strategies and plans [4]. Fuel poverty (sometimes referred to as energy poverty) occurs when a householder cannot afford basic comfort levels of heating (other energy use is also included but in this paper we refer to heating levels). In the UK, it was estimated that 10.9% of all households were living in fuel poverty in 2011 [5]. Its causes are recognised as the combination of three main factors: low income, poor energy efficiency and high fuel prices [6], the latter being the dominant driver [7].

The issue of affordable warmth also features prominently on the UK national political stage. The Warm Homes and Energy Conservation Act of 2000 set a legally binding target for the UK government to eradicate fuel poverty by 2016 [8]. However, in recent years the issue of fuel poverty has not remained consistently under focus within the national political debate. The government recognised within the 2013 Energy Bill that its 2016 target was not achievable in the time frame. A new target is due to be set this year [9].

Fuel poverty is not just an issue in the UK and Ireland, but exists across Europe.

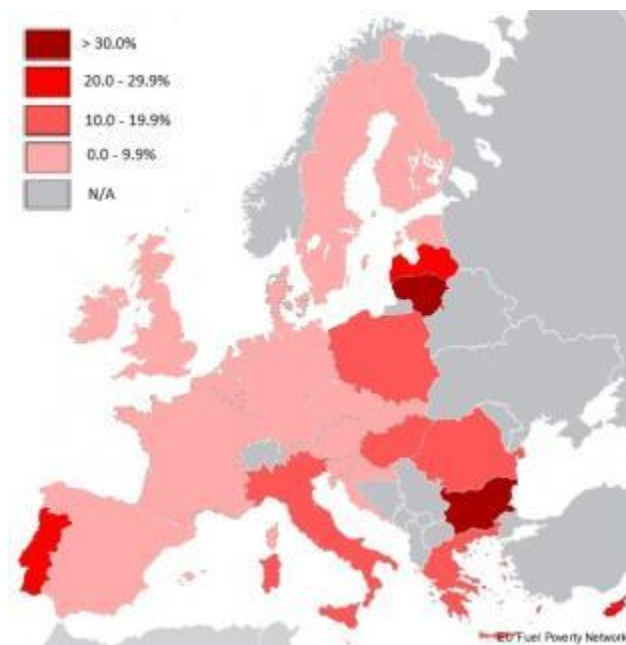


Fig. 1: % of households unable to afford to keep their home adequately warm (data source: EU SILC 2011) [10].

However, energy-efficiency measures alone will not be sufficient to eliminate fuel poverty [4]. Efficient and low-cost provision of heat through DH could therefore make a significant contribution to fuel poverty reduction in the domestic sector.

#### Current modelling tools

As discussed previously, use of mapping tools is commonplace for district heating planning and development. This research considers the appropriateness of tools and techniques for capturing

opportunities for achieving multiple aims with district heating, such as fuel poverty reduction alongside carbon reduction, and financial return on investment.

Current methods are predicated on modelled or real heat-density data based upon today's heat loads. For example, the National Heat Map [11], developed by the Department for Energy and Climate Change in the UK, displays modelled heat demand at a postcode resolution to offer an initial view of whether district heating might be technically and economically feasible within an area. Funding awarded through the HNDU for feasibility studies in England and Wales has enabled local authorities to commission consultants to take a similar approach at a more detailed level, adding in information about secondary heat sources, public buildings, and potential piping routes with the aim of developing business plans "which can be used to attract commercial investment" [12]. In Scotland, the Scottish Government opted to create a more detailed planning map for the whole of the country rather than commissioning consultants for each individual region. The energy-efficiency levels of much of the UK's building stock are not taken into account within heat maps, despite the fact that generally the housing stock is poorly insulated. Other considerations such as fuel poverty levels can be added in to these maps at the discretion of the local authority, but in general the primary objective of undertaking these exercises is to identify the site locations with the maximum potential for financial payback.

The effectiveness of modelling tools for stimulating new district heating projects is still contested. For example, at a meeting of 39 local authorities and housing associations as part of the Vanguards network, members of the meeting felt that modelling tools did not help to overcome the significant and complex barriers preventing individual projects being installed on the ground. They felt that the experience and knowledge of individuals within local authorities was what was needed [13]. However, other members felt that further development of tools was required.

Current modelling tools using heat demand mapping as their basis don't allow local authorities to look at aspects (other than revenue generation) that might motivate their involvement in the development of district heating.

#### STATE OF THE ART

This work investigates the incorporation of social considerations within the development process for district heating. We assess the appropriateness of existing tools for incorporating these considerations within the decision-making process and propose recommendations for better strategic planning.

We pose the following research questions:

- What are the main motivations for local authority involvement in district heating in the UK?
- What decision criteria are used to identify potential schemes, and are these aligned with original motivations?
- What decision-support tools are used by local authorities in the pre-feasibility stage?
- Do these tools support developments that meet the main motivating objectives of local authorities?

## **METHODS**

In order to understand the motivations, decision criteria and use of modelling tools in local authority-led district heating schemes, we conducted 11 semi-structured interviews with key actors in 6 local authorities in England and Scotland, as well as 3 private sector companies and 2 other public sector stakeholders. These interviews were transcribed, and thematic analysis was conducted.

In addition, we reviewed a range of policy documents; the policy context in the UK is moving rapidly and some significant policy changes were implemented during the timescale of this project.

Relevant quantitative data was collated to develop a simple spatial mapping tool that addresses issues arising from the results of the interview work. This tool and a brief analysis of its benefits are described in the discussion section.

## **RESULTS**

### Motivations and decision criteria

Many local authorities see district heating as bringing benefits for tackling fuel poverty and this is often cited in press releases as a key motivation for developing schemes. For example, the Scottish Government [14] and Hull City Council [15] have both recently announced the development of heat networks to support fuel poverty reduction.

However, a key part of this research was to investigate whether social criteria, such as a reduction in fuel poverty, were incorporated into the down-select for project sites, given that our literature review highlighted that many of the support tools currently available focus on techno-economic considerations.

It became clear from analysis of the interviews with the six local authorities that the motivations for developing district heating vary widely between authorities. There is no consensus on the benefits that organisations are looking for from district heating.

Social criteria were important, not just in terms of fuel poverty alleviation, but also for regeneration of council-owned housing stock. District heating 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. Especially where capital funding was available, this was seen as a way to reduce the costs of heating and maintenance for residents and the local authority, respectively.

Carbon reduction was often mentioned as an important driver. There was also a financial consideration for carbon reduction, as public sector organisations not covered by the EU emissions trading scheme are required to buy allowances for the tonnes of carbon they emit under the Carbon Reduction Commitment (CRC) energy efficiency scheme [16]. Therefore the ability to deliver carbon savings through use of district heating can offer financial savings to public bodies.

Alongside social and environmental concerns, economic motivations were prominent. Local authorities focused on increasing the competitiveness of their local region, using district heating to attract industrial activity to the area and thus creating more local jobs.

Despite a clear articulation of the local authority's drivers for wanting to develop district heating, the decision criteria used for planning and construction of a business case for a scheme did not necessarily reflect these drivers. By analysing the interviews and noting the mention of motivations and decision criteria, the following broad areas and rankings of importance were revealed<sup>1</sup>.

---

<sup>1</sup> Technical feasibility is, of course, important, irrespective of the underlying motivations.

Table 1 Observed rankings indicating the relative number of times motivations were stated by local authorities planning district heating schemes vs. the number of times different decision criteria were mentioned for use within planning to construct a business case for a scheme.

Motivation	Decision Criteria
<p>1. Social</p> <p>Regeneration of housing stock</p> <p>Fuel poverty</p>	<p>1. Economic</p> <p>Where are opportunities to offer lower-risk, financial returns to:</p> <ul style="list-style-type: none"> <li>- Potential investors?</li> <li>- The local authority?</li> </ul>
<p>2. Environmental</p> <p>Carbon reduction</p>	<p>2. Social</p> <p>Where are opportunities to use ECO funding for a residential DH scheme?</p> <p>Are there opportunities to add on households to a planned commercially competitive scheme?</p>
<p>3. Economic</p> <p>Regional competitiveness e.g. attracting industries wanting low-carbon heat and electricity</p> <p>Local economic growth</p>	<p>3. Environmental</p> <p>Will the carbon savings offered by a scheme reduce costs on the CRC?</p>

Whilst the rankings are obviously subject to interpretation in our coding and, given the small sample, are not necessarily statistically significant, the mismatch between motivations and decision criteria is striking, and clearly supported by the recorded narrative.

#### Current use of mapping tools

The next stage of this research goes on to explore in more detail how local authorities are currently using mapping tools within the DH development process.

As mentioned previously, the HNDU and the Scottish Government are encouraging use of heat mapping by local authorities to identify potential development sites and attract financial investment [17]. Mapping was perceived by all those interviewed to have an important role in the planning process and was often part of the pre-feasibility decision-making. Many of the organisations were in the process of developing a heat map, or had ambitions to develop one to assist in the

selection of suitable heat network projects. There were no common tools used; many had created bespoke methods and had used consultants to undertake feasibility studies.

In England, the DECC heat map was mentioned as an initial base upon which to do early planning and “give a level of confidence that there is enough heat demand in the city” (Interviewee in one English local authority). The data from this map was seen as a useful basis upon which to develop a more detailed city-scale map which also included factors such as anchor loads, waste heat plants, and any sort of constraints. In England councils were also hoping to receive funding from HNDU to support the development of maps. The current application of these maps predominantly aims to identify sites that are most likely to offer a commercial opportunity and, therefore, the maps focus on characteristics, such as current heat demand, that indicate likely technical and economic feasibility of a potential scheme. Local authorities clearly possess a wealth of local knowledge about the locations of areas with social deprivation or regeneration requirements, and these were considered informally in many cases. However, the use of such tools to formally build in consideration of wider social objectives of the council had not generally been considered:

*“At the moment we’ve really not looked at how we could deploy a heat mapping tool to community regeneration areas.”* (Scottish local authority)

The Scottish Heat Map, soon to be launched, is an exception to the use of heat mapping that focuses primarily on techno-economic criteria. The Scottish Government’s activity in this area has concentrated on building a heat map for Scottish local authorities that enables consideration of both fuel poverty reduction potential and commercial model potential. This is the best example of a planning tool which enables the construction of a business case for more than just financial benefits. At this stage the map is not yet complete so the role of mapping and its effectiveness for stimulating strategic development approaches cannot yet be assessed, although this is certainly an area for further research.

#### Gap between use of mapping and motivations of stakeholders

In the context of budget cuts in local authorities and increasing demand on council services [18], district heating projects need a strong business case for them to be given the go-ahead over other competing priorities. Clearly articulated and consistent objectives agreed at a strategic level are essential to enable such a business case to be constructed. The tools offer an evidence base to convince decision makers that district heating is worth investing time or capital in over other projects.

*“I think that gives you more evidence and evidence is useful if you’re writing applications and trying to make a business case”* (English local authority)

The interview analysis indicated that, particularly in England, there is an opportunity for local authorities to adjust their planning and development process to enable a better reflection of their authority’s chosen objectives when constructing a business case for a project. The current approach of the HNDU encourages the use of decision criteria to focus on where financial income can be generated for the provider. However, this approach will not always deliver effectively for the alternative motivations, such as fuel poverty reduction.

From the interviews there was a clear mismatch between the motivations of local authorities and the decision criteria that they use to identify feasible sites for DH. The next section explores how current mapping techniques could be adapted to better incorporate these motivations in the decision-making process. It also explores the significance of including data to represent social criteria on district heating planning.

#### Issues of mapping heat demand

In all of the existing tools and assessment methods currently used the estimated heat demand of an area is the primary metric. There are, however, two issues arising from the use of estimated heat demand as the main criteria for assessing feasible DH sites:

1. It is particularly difficult to assess heat demand for households in fuel poverty, as they, by definition, are suppressing their energy use due to financial constraints. Fuel-poor households, particularly those with low incomes, have lower heat demand per m<sup>2</sup> floor space than non-fuel poor households [19]–[21]. This, therefore, makes them a less attractive area for profit-driven providers to invest in DH. However, if affordable warmth was provided via DH then the actual heat demand may be higher. It is particularly difficult to predict the heat consumption of fuel-poor households since they are more vulnerable to fuel price rises and other financial shocks [4]. This poses difficulties for sizing of systems and predicting their financial pay-back periods, and also the setting of heat tariffs to enable covering of basic maintenance and fuel costs.
2. Heat demand does not give an indication of the energy efficiency of a building. It may be that insulating the fabric of the property is a more beneficial route to reduced energy consumption than provision of district heating.

In addition, heat demand is used to support decisions on techno-economic criteria which, when used on its own, drives decisions toward priorities in these criteria

over social factors. Taking these three aspects together means that factors related to fuel poverty are excluded from the decision which means that schemes with potential to address fuel poverty might be overlooked.

For local authorities seeking to develop a robust, commercially viable business case that also meets objectives of reducing fuel poverty we propose that a metric related to heat demand, e.g. housing density, be used instead. This gives an alternative metric of techno-economic feasibility, as it is directly related to demand, but also allows other factors to be represented. Combined with other data on fuel poverty and tenure status, this would provide evidence to build a business case and gain political and stakeholder support for schemes that meet social criteria whilst still including technical and economic feasibility criteria.

#### Developing a multi-criteria spatial mapping tool

How can mapping tools allow flexibility for local authorities to adapt them to explore a mix of objectives, not just for maximum financial return? To explore this question, a simple mapping exercise has been completed using publically available data sets, including social data, to compare the outputs of existing tools.

First, we explore whether housing density could be used as a proxy for indicating potential technical and economic viability for DH, instead of the current assessment using modelled heat demand. Second, we compare an existing map with one which includes social criteria as an initial indication of how this might change the prioritisation of potential schemes and the construction of business cases that bring multiple benefits.

The mapping has been conducted at a census output area level (approximately 150 households per area). Each area has been scored based on whether it exhibits characteristics to suggest there are technical, economic and social benefits of DH to be realised in that area<sup>2</sup>. Thematic maps are created based on a calculated score for each area. The scoring calculation is summarised in figure 2. Areas within the top 10 percentile for a considered characteristic receive an increased score. When multiple characteristics are considered they are weighted to represent their importance within the business case construction. In this example, where social criteria are added in, for figure 5 the housing density has been weighted as 60%, and social criteria of fuel poverty and index of

---

<sup>2</sup> Details on how the scoring has been calculated can be found at in the authors report to the funders [23]. The mapping work is available publically through an interactive online tool called the Leeds Heat Planning Tool <http://sure-infrastructure.leeds.ac.uk/leedsheat/>.

multiple deprivation are weighted jointly as the remaining 40%.

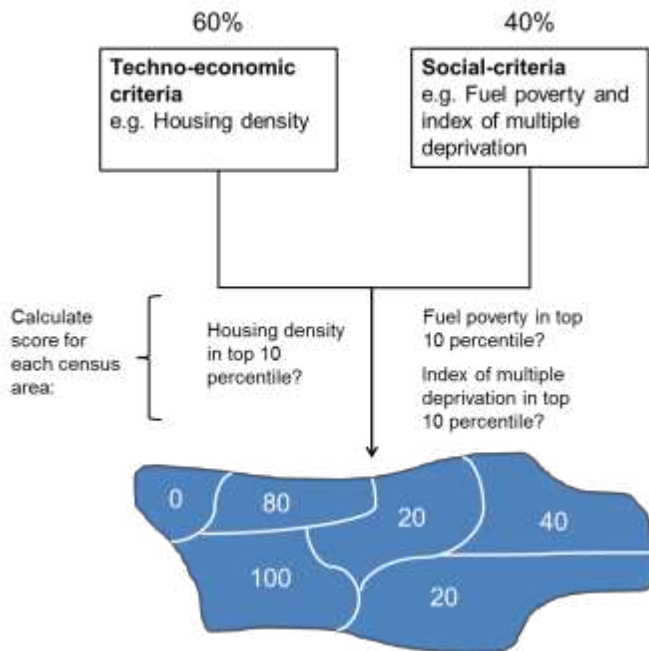


Fig. 2 Summary of how scoring was calculated to assess census output areas in Leeds based upon multiple criteria

## DISCUSSION

### Comparison of mapping

Three maps of a case study in Leeds, UK are displayed in appendix A for comparison. Figure 3 shows an excerpt from the National Heat Map [11], showing modelled residential heat demand in 2012. Figures 4 and 5 display the alternative maps produced to consider housing density levels and the addition of social criteria.

A comparison between figure 3 and figure 4 shows that housing density gives a proxy for the areas of highest heat demand. There is a correlation between the locations of the areas with the densest residential heat demand on the national heat map and the densest housing. The use of housing density instead of heat demand ensures that the analysis is not affected by issues such as under-heating due to fuel poverty. In addition, the use of freely available data provides a quick and easy means for local authorities to start assessments where more detailed heat demand data isn't available.

The addition of social characteristics into the analysis allows prioritisation of the technically suitable areas. In figure 5 there is a clear priority area that has the potential to achieve social benefits with district heating. This is indicated on the map. This area contains a high housing density combined with households in fuel poverty with high levels of multiple deprivation. When these considerations are not used it is not clear which area might achieve social goals. For a local authority wishing to use district heating for regeneration or fuel

poverty reduction this mapping helps to prioritise areas by explicitly reflecting their strategic motivations within the early planning process.

Even with the simple use of open data in this example there is sufficient information to strengthen an early-stage business case. The use of multiple criteria can align the case with the strategic priorities of a local authority and make it more likely to persuade decision makers of the value of district heating for their region.

### The role of planning tools in context

We have shown that simple spatial mapping of freely available data may support decision-making in local authorities where the aim is to achieve alternative social value outcomes to those that are solely economic. This represents a first step towards better decision-making to reflect the multiple goals of local authorities. However, we recognise that the development process is significantly more complex than communicating data effectively. It is important to remember that planning tools facilitate a particular mind-set and focus that can exclude others, e.g. in the UK the commercial and the social have been separated. However, it is not necessarily the case that the mere inclusion of socio-economic data within mapping tools would enable local authorities to overcome the overriding context of budget cuts and more urgent priorities for a local authority. It is well recognised within the literature that the surrounding regime and institutions in the wider energy system are just as critical to the successful uptake of a technology as the physical or economic case for a technology in isolation [22]. Planning tools are one way to support actors to negotiate through a resistant regime. We recognise that such tools do not provide the complete solution to such complex problems. However, we argue that they provide an important evidence base to persuade decision makers. The use of tools could in fact be more effective if they were better aligned to the strategic goals of the local authority.

## OUTLOOK

We believe there is a need to further understand how such tools are treated and valued within the decision-making process. Our future work will seek to explore whether evidence of social benefits from successful DH projects could be brought into decision-making for future schemes with the broader aim of reducing fuel poverty across Europe. We also propose to broaden the data included within early planning tools to bring an understanding of the context of the wider energy system.

## CONCLUSION

DH can offer a range of environmental, economic and social values to the area it serves. These values are perceived differently by different actors. For example,

this research highlights the variation in ambitions and motivations for encouraging development of DH between local authorities in the UK. Social motivations such as fuel poverty alleviation featured highly in many authorities' strategic aims for projects, but, for others, DH was an opportunity to create revenue or attract industry and jobs to their area.

The complex process of DH development requires a number of factors to align simultaneously to allow a project to go ahead. Consideration and articulation of the motivations and drivers of the actors involved in developing a scheme is essential to the success of this process. Mapping tools have a clear supporting role to offer in the early planning stages and construction of an initial business case. However, the value of these tools is diminished if they are not aligned to the strategic aims of the decision makers in question.

The methods currently used focus primarily on identifying potential schemes that would generate the maximum financial profit and attracting financial investors to fund the schemes. Although this is an appropriate course of action for some local authorities, for others with more socially driven strategic aims the mapping tools used will not offer the right information to construct a suitable business case.

Tailored specifications for mapping exercises, created in line with explicit strategic objectives, would allow consideration of a much broader set of criteria and data which better reflect the aims of the local authority.

We conclude that, for a particular locality, the potential value of DH could be articulated better through the methods proposed here. The use of simple spatial planning tools, using open data and metrics that reflect heat density (rather than demand) and social criteria such as fuel poverty and deprivation, could be used to build the business case for schemes that would support social as well as economic objectives.

## **ACKNOWLEDGEMENT**

This work was funded by the Cheshire Lehmann Fund. The wider findings of this work can be found in the report by these same authors [23]. The authors are grateful for the funding and would also like to thank those that participated in the interviews. Thanks also to Professor Peter Taylor for helpful comments and advice throughout and Dr Katy Roelich for insightful comments on a draft of this paper.

## **REFERENCES**

- [1] DECC, The Future of Heating: Meeting the Challenge, Department of Energy and Climate Change, London (2013).
- [2] C.S.E. Bale, T.J. Foxon, M.J. Hannon and W.F. Gale, "Strategic energy planning within local authorities in the UK: A study of the city of Leeds", Energy Policy, 2012, Vol. 48, pp. 242–251.

- [3] DECC, Heat Networks Delivery Unit, London (2013)  
<https://www.gov.uk/government/publications/heat-networks-funding-stream-application-and-guidance-pack>.
- [4] J. Hills, Getting the measure of fuel poverty: final report of the Fuel Poverty Review, (2012).
- [5] DECC, Fuel poverty 2011 detailed tables - Low income high costs indicator. (2013), Available from: <https://www.gov.uk/government/publications/fuel-poverty-2011-detailed-tables>
- [6] D. Üрге-Vorsatz and S. Tirado Herrero, "Building synergies between climate change mitigation and energy poverty alleviation." Energy Policy, 2012, Vol. 49(0), pp.83–90.
- [7] D. Jenkins, L. Middlemiss and R. Pharoah "A study of fuel poverty and low-carbon synergies in social housing" Heriot-Watt University, Scotland (2011).
- [8] UK Parliament, Warm Homes and Energy Conservation Act, London, (2000).
- [9] UK Parliament. Energy Bill Grand Committee (4th Day) Amendment 50J, Moved by Baroness Verma. London (2013).
- [10] C. Wand, % of households unable to afford to keep their home adequately warm. <http://fuelpoverty.eu>, (2013).
- [11] DECC, The National Heat Map [Online] (2012). [Accessed 13.05.13]. Available from: <http://tools.decc.gov.uk/nationalheatmap/> .
- [12] Government Digital Service, £2m awarded for local authority low carbon heat networks [Online] (2014), [Accessed March]. Available from: <https://www.gov.uk/government/news/2m-awarded-for-local-authority-low-carbon-heat-networks> .
- [13] Vanguard's Network, District Heating Policy Options in the UK: Workshop report. Sheffield City Council: District Heating Development Ltd, University of Edinburgh (2013).
- [14] CHPA, District heating to tackle Scottish fuel poverty [Online], (2014), [Accessed March]. Available from: [http://www.chpa.co.uk/district-heating-to-tackle-scottish-fuel-poverty\\_2070.html](http://www.chpa.co.uk/district-heating-to-tackle-scottish-fuel-poverty_2070.html) .
- [15] Yorkshire Post, District heating scheme 'would cut fuel poverty' [Online] (2013), [Accessed March]. Available from: <http://www.yorkshirepost.co.uk/news/main-topics/local-stories/district-heating-scheme-would-cut-fuel-poverty-1-6084486> .
- [16] GOV.UK, Reducing demand for energy from industry, businesses and the public sector, London (2014).



- [17] Scottish Government. Heat mapping - a guide - For use by local government or other contracted organisations. 2013.
- [18] P. Butler, Local council cuts will lead to skeleton service, warns Tory chair of LGA, *The Guardian* (2013).
- [19] A. Druckman and T. Jackson, "The carbon footprint of UK households 1990–2004: a socio-economically disaggregated, quasi-multi-regional input–output model", *Ecological Economics*, 2009, Vol. 68, pp.2066–2077.
- [20] I. Preston, V. White and T. Bridgeman, *Distribution of Carbon Emissions in the UK: Implications for Domestic Energy Policy*. York: Joseph Roundtree Foundation, (2013).
- [21] Consumer Focus, *Understanding Fuel Expenditure - fuel poverty and spending on fuel*. London, (2011).
- [22] A. Smith, J.-P. Voß and J. Grin, "Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges.", *Research Policy*. 2010, Vol. 39, pp.435–448.
- [23] R. Bush, C. Bale and P. Taylor, *Spatial mapping tools for district heating (DH): helping local authorities tackle fuel poverty*. Leeds: Report for Cheshire Lehmann Fund, (2014).

APPENDIX A



Fig. 1 Extract from the DECC National Heat Map showing modelled residential heat demand in Leeds, UK.



Fig. 2: Map showing census output areas with housing densities in the top ten percentile for Leeds, UK.



Fig. 3 Map showing census output areas scored for high housing density (60% weighting), and two social indicators (40% weighting) of fuel poverty levels and the index of multiple deprivation for Leeds, UK.