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Scaling up local energy infrastructure; An agent-based model of the emergence of district heating networks

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ABSTRACT

The potential contribution of local energy infrastructure – such as heat networks – to the transition to a low carbon economy is increasingly recognised in international, national and municipal policy. Creating the policy environment to foster the scaling up of local energy infrastructure is, however, still challenging; despite national policy action and local authority interest the growth of heat networks in UK cities remains slow. Techno-economic energy system models commonly used to inform policy are not designed to address institutional and governance barriers. We present an agent-based model of heat network development in UK cities in which policy interventions aimed at the institutional and governance barriers faced by diverse actors can be explored. Three types of project instigators are included – municipal, commercial and community – which have distinct decision heuristics and capabilities and follow a multi-stage development process. Scenarios of policy interventions developed in a companion modelling approach indicate that the effect of interventions differs between actors depending on their capabilities. Successful interventions account for the specific motivations and capabilities of different actors, provide a portfolio of support along the development process and recognise the important strategic role of local authorities in supporting low carbon energy infrastructure.

1. Introduction

Local energy infrastructure[1] is becoming increasingly important in the transition towards a low carbon economy (Burt et al., 2012; Realising Transition Pathways Engine Room, 2015). Delivery and operation of infrastructure at a local scale can contribute to multiple aims of energy policy; reducing carbon emissions, providing affordable energy and securing local economic benefits and control (Hall and Roelich, 2015; Roelich and Bale, 2014). However, those attempting to engage with local energy infrastructure currently face many barriers to scaling up (i.e. increasing the size and/or number of projects), which limits their potential to contribute to these aims.

There is currently a lack of policy support for energy infrastructure at the local scale and the focus of regulation on national-scale actors serves to increase the challenges for those attempting to deliver or operate local energy infrastructure (Hall and Roelich, 2015). While the role of local energy infrastructure in a successful energy system transition is acknowledged (Realising Transition Pathways Engine Room, 2015; Seyfang et al., 2013) there has been little focus on scaling up of these schemes, which further marginalises its potentially valuable contribution (Ekins et al., 2013).

This paper addresses the question of how scaling up the role of local energy infrastructure can be accelerated through appropriate policy intervention. We use the example of the development of heat networks in the UK, but the methods and analysis are broadly applicable in both technical and geographical terms. In Section 2 we review key literature in the field and propose a modelling approach to address this challenge. In Section 3 we present our methods and discuss key results in Section 4. In Section 5, we discuss the systemic insights gained and the usefulness of the agent-based approach when considering scaling up local energy infrastructure. We conclude in Section 6 with recommendations for energy policy.

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[1] We use the term 'local energy infrastructure' (otherwise frequently called decentralised or distributed infrastructure) to refer to that infrastructure which is delivered locally by non-traditional actors in energy provision, who operate at a local scale, including local authorities, communities and social enterprises. This includes, for example, district heat networks, microgeneration, demand management, smart grid technologies and small-scale storage.

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2. Context

In the UK, as in some other countries, there are clear and ambitious targets for greenhouse gas emissions reductions (HM Government, 2008). Current public policy related to energy systems is focused mainly on micro-level demand-side efficiency measures and macro-scale regulatory interventions on the supply-side. Micro-level demand-side measures include schemes to encourage retrofit in households such as the Energy Company Obligation (HM Government, 2012). Macro-scale measures on the supply-side include the Renewable Obligation, which aims to stimulate investment in renewable generation technologies by placing an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources (Ofgem, 2015).

These measures overlook the local scale of activity and the important role of business models in driving system change, as well as technology adoption. In the following sections we outline (i) why local energy infrastructure is important to energy system transition in the UK, (ii) why local actors may engage in infrastructure for different reasons, with different outcomes and (iii) the important influence of business models in driving system change. (vi) We go on to describe an approach to modelling that will enable us to explore the scale up of local energy infrastructure in a way that better reflects some of the key characteristics and benefits of local infrastructure. We use the case study of the development of heat networks in the UK to explore these issues.

2.1. Local energy infrastructure

Driven in part by challenging targets for greenhouse gas reduction, there is an increasing trend for localisation of physical energy infrastructure; towards smaller units of generation and smarter distribution and control systems to connect supply more closely with managed demand (Burt et al., 2012; Rydin et al., 2013). Infrastructure delivered at the local scale is cited as have many advantages over more centralised systems including resilience (O'Brien and Hope, 2010), increased potential to incorporate renewable technologies (Alanne and Saari, 2006) and reduced transmission losses (Burt et al., 2012).

Heat networks are one example of local-scale, and potentially low-carbon, energy infrastructure. These networks have the potential to significantly reduce the energy intensity and carbon emissions of heat provision, particularly when heat is sourced from sources such as biomass combined heat and power (CHP) generators or waste industrial heat (Eriksson et al., 2007). In the UK, only 1% of the population is currently supplied with heat from a network, as compared to more than 60% in Denmark, Poland and Estonia (Euroheat, 2009).

However, the technology itself is considered mature, and the barriers to adoption of heat networks in the UK are found to be related to the challenge of complex interactions between stakeholders and overcoming the lock-in of building-level heating technologies and the centralised provision of gas and electricity (BRE et al., 2013). This work is focused on the challenge of stakeholder interaction in heat network development.

2.2. Local actors

The smaller scale of technologies and closer connection between supply and end-users presents an opportunity for new actors to engage in local energy infrastructure, including municipalities, community groups and social enterprises. There is increasing evidence that the motivation of local actors for engagement in energy provision is very different to mainstream actors and much more focussed on social and environmental outcomes (Roelich and Bale, 2014; Seyfang et al., 2013).

Local authority and community involvement in energy infrastructure provision has, however, been minimal since nationalisation in the 1940s (Fouquet and Pearson, 1998). The UK has a highly centralised system of infrastructure provision, supported by regulation that is intended to create competition between providers wherever this is not prohibited by natural monopolies (Mitchell and Woodman, 2010). Particularly in the utilities, this has resulted in national scale planning and operation of infrastructure.

Recent policy shifts, however, have seen a devolution of power to municipal scale actors through the 2011 Localism Act (HM Government, 2011) and City Deals (Deputy Prime Minister's Office, 2011), which include an increasing responsibility for local infrastructure placed in the hands of local authorities and city regions. Furthermore, local government and community groups are noted as being key to delivering a host of energy strategies in the UK, including the heat strategy (Department of Energy and Climate Change, 2013).

Local authorities have the opportunity to use this increased autonomy to plan for the development and operation of infrastructure locally. This creates space for new actors at the local scale and allows local authorities and community organisations to become infrastructure providers and capture the benefits that this may bring. In addition to the national level strategies for development of heat networks, there is interest at the municipal scale, where local authorities recognise the potential for heat networks to contribute to fuel poverty reduction by providing a lower cost source of heat, as well as other economic and environmental benefits (Bale et al., 2014b).

Examples of local development of heat networks already exist (e.g. Islington Bunhill and Aberdeen Heat and Power (Bale et al., 2014a)), but as isolated niche examples that are far from becoming mainstream in the UK. They are implemented by a range of different actors (i.e. instigators) including municipal authorities, community organisations, cooperatives and private enterprises. A multitude of barriers hold back these organisations unless they have a very specific set of capabilities and a favourable local context (Department of Energy and Climate Change, 2013).

2.3. Business models and decision making

The development of local energy infrastructure is more complex than a simple decision to invest in a single technology. This is particularly the case when involving non-traditional actors who: have a broader range of motivations; target different customer segments; and target the creation of different forms of value, beyond economic outcomes (Foxon et al., 2015). Determining how to deliver benefits and capture value and with whom to engage (often referred to as a business model (Chesbrough and Rosenbloom, 2002; Teece, 2010)) is crucial to scaling up local infrastructure delivery and operation (Foxon, 2011; Hannon et al., 2013), but is frequently overlooked when analysing local infrastructure (Hall and Roelich, 2015). Therefore, it is important to understand heterogeneous non-traditional actors with different motivations and capabilities, who interact with other actors and organisations in the system.

The development of a viable local infrastructure business models requires instigators to navigate a series of project stages, including mobilisation, feasibility assessment, securing finance, procurement and operation (BRE, 2013). Decisions in relation to these project stages are made within the constraints of the social, technical and policy environment. Instigators' ability to navigate these stages will also be impacted by their experience and capacity, and the requirement for them to interact with other actors involved in heat network development, as well as with potential customers. It is therefore not an instantaneous decision nor is it undertaken based solely on techno-economic criteria. This makes analysis of how to accelerate scaling up more challenging than determining how to improve the financial viability of isolated investment decisions. Instead, it requires analysis of a process of connected decisions and interactions within a specific social, technical and policy setting.