Emergence of District Heating Networks; modelling alternative business models

Topic:

5.1 Business models, organisations, and alternative valuation

Introduction

The challenges of climate change mitigation require an infrastructure transition that is unprecedented in scale and speed. The currently dominant business models for infrastructure development and operation are unfit for this purpose. Utility provision infrastructure (i.e. energy, water, transport and waste removal), in particular, is characterised by carbon intensive generation and supply for unconstrained and unsustainable levels of demand [1]. Alternative business models exist that operate more resource efficient physical infrastructure and are capable of creating and capturing wider forms of social and environmental value. These, however, exist only as isolated 'niche' examples of good practice and are far from becoming mainstream. In this contribution, we present an agent based model (ABM) for investigating the potential mainstreaming of alternative business models. Our model concentrates on the actors involved in an infrastructure business model throughout project development and operation, embedded in the broader socio-technical context. This builds on previous work that studied the barriers to MUSCos (Multi-utility service company) business models [1] and local authority energy planning [4,5].

Our modelling approach draws on the socio-technical transitions perspective [6] and co-evolutionary theory [7]. A co-evolutionary approach forces the clarification of an interdisciplinary system representation that includes physical infrastructure, actor behaviour and their interactions, and the relevant policy environment. It allows us to go beyond standard economic assumptions of rational choice and a demand-driven market to capture complex behaviours and interactions between agents across both the demand side and the system of provision. Agent-based modelling (ABM) is able to capture such complex interactions between policy interventions, social and technical structure, and individual behaviour [8,9], and explore the emergence of different systemic patterns. While agent-based models of social systems abound, only recently work has emerged to simulate the long-term development of infrastructure and other socio-technical systems [10,11]. In this contribution we describe the development and results of an agent-based sociotechnical model that goes beyond end-use technology adaptation to the emergence of alternative infrastructure business models, demonstrated by the roll-out of district heating (DH) networks in the UK.

District Heating in the UK

District heating (DH) networks have the potential to significantly improve the energy efficiency and carbon intensity of heat and hot water supply to domestic and commercial buildings [12], particularly where heat can be sourced from combined heat and power (CHP) generators or waste heat sources. Although this potential is recognised by the UK government, progress in the development of heat networks is still very slow. The UK has very low penetration of heat networks with only around 1% of the population supplied with heat from a network [13]. This is much lower than most European countries where some, including Denmark, Poland and Estonia, have more than 60% of the populations heat supply provided by district heating [13].

Significant barriers to a larger roll-out of DH networks in the UK have already been identified in a number of studies [4,14,15]. The barriers identified in these studies arise from factors including regulatory restrictions, actor capacity and knowledge limitations and a lack of established market mechanisms (for both project financing and sale of heat). This study aims at capturing the complex interplay of these barriers along individual project development timelines and across the entire socio-technical system.

An Agent-Based Sociotechnical Model

The purpose of our model is to investigate the potential for different actors to implement DH networks, and how policy interventions impact on their success.

Modelled entities: The model includes three basic types of agents: instigators who seek to develop a heat network; heat demand agents; and heat source agents. The instigators are differentiated into community organisations, local authorities and commercial developers. Heat demand agents are further classified into private housing (including owner-occupied and private rented), social housing (both local authority owned and other social housing providers), public (for example swimming pools, schools, hospitals and council offices) and commercial. Heat source agents represent existing sources of waste heat that can be integrated with a DH network.

Key processes: The model procedure is driven by the actions of the instigator agents. These agents proceed through three phases of development: idea generation and project scope; feasibility and business case; and procurement and build. In each phase, the ability of the instigator to complete certain actions is determined by a set of attributes they possess. In the idea phase, the instigator must have the *institutional knowledge* to consider DH network development. In the feasibility phase, instigators must have *access to feasibility finance* to proceed. In the final procurement and build phase, instigators must have *access to capital finance*, the *capability to negotiate procurement contracts* and be able to *manage customer relationships*.

Scenarios and Analysis: The successful completion of a DH project in the model is determined by three factors:

1. the physical distribution of the different types of heat demand (commercial, private domestic, social domestic and public),
2. the attributes possessed by the three different types of instigators, and
3. parameters representing the policy regime and possible interventions (e.g. the availability of feasibility finance).

In our analysis we describe the relative importance of attributes in determining success for the different instigators, and how specific policy interventions lead to the unequal promotion of certain types of instigators and projects over others. We show the results of different scenarios that represent policy interventions, such as government support for feasibility work and the provision of low interest capital finance for public projects. The results indicate that different interventions enable the creation and capture of different forms of value from DH projects. Different organisations, by virtue of their purpose, motivations and geographical extent, are capable of generating different kinds of social and environmental value, as well as economic value at different scales. Local authority projects are more likely to address fuel poverty whereas community projects are more related to environmental benefits.

Conclusions

The development of our model has brought useful insights into the relationship between the attributes and motivations of different DH network developers and the type and scale of projects they successfully create. The approach of developing an agent-based model of district heating has highlighted that the key drivers are intimately related to both the physical geography of the built environment stock and the motivations of a number of key actors that include local authorities, commercial developers and potentially community organisations.

The model we have presented here is based on a highly interdisciplinary research approach that integrates technical infrastructure and building stock models with agents that make decisions based not only on economic considerations but also based on their capabilities and local interaction. This interdisciplinary approach is crucial in studying infrastructure systems, which, due to their scale and key role in providing societies needs, are tightly regulated, difficult to finance and capable of causing enormous environmental damage. The agent-based modelling approach also allows us to connect the micro-level analysis of barriers and actions to the wider governance regime. Barriers at the micro-scale are often a manifestation of a meso- and macro-scale policy regime and landscape that favours the incumbents. An agent-based model can connect changes to the policy regimes back to the micro-level of actors implementing alternative infrastructure business models.

References

[1] Roelich, K. *et al.* Towards resource-efficient and service-oriented integrated infrastructure operation. *(submitted)*.

[4] Bale, C. S. E., Foxon, T. J., Hannon, M. J. & Gale, W. F. Strategic energy planning within local authorities in the UK: A study of the city of Leeds. *Energy Policy* **48,** 242–251 (2012).

[5] Knoeri, C., Goetz, A. & Binder, C. R. Generic bottom-up building-energy models for developing regional energy transition scenarios. in *9th Conf. Eur. Soc. Simul. Assoc.* (2014).

[6] Geels, F. Technoogical transitions as evolutionary reconfiguration processes: a multilevel perspective and a case-study. *Research Policy* **31**, 1257-1274 (2002).

[7] Foxon, T.J., A coevolutionary framework for analysing a transition to a sustainable low carbon economy. *Ecological Economics* **70**, 2258-2267 (2011).

[8] Grimm, V. & Railsback, S. F. *Individual-based Modeling and Ecology*. (Princeton University Press, 2005).

[9] Janssen, M. A. & Ostrom, E. Governing socio-ecological systems in *Handbook of Computational Economics II: agent-based computational Economics* (eds. Tesfatsion, L. & Judd, K. L.) (Elsevier, 2005).

[10] Van Dam, K. H., Nikolic, I. & Lukszo, Z. *Agent-Based Modelling of Socio-Technical Systems*. (Springer, 2013).

[11] Bergman, N. *et al.* Modelling Socio-Technical Transition Patterns and Pathways. *J. Artif. Soc. Soc. Simul.* **11,** (2008).

[12] Department of Energy & Climate Change. *The Future of Heating: Meeting the challenge*. (2013).

[13] Euroheat. District Heating and Cooling Statistics. (2009).

[14] Department of Energy & Climate change. Research into barriers to deployment of district heating networks. (2013).

[15] Hawkey, D., Webb, J. & Winskel, M. Organisation and governance of urban energy systems: district heating and cooling in the UK. J. Clean. Prod. **50,** 22–31 (2013).