Technological Forecasting & Social Change xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Infrastructure transformation as a socio-technical process — Implications for the governance of energy distribution networks in the UK

Ronan Bolton [a,*], Timothy J. Foxon [b]

[a] Science Technology and Innovation Studies, School of Social and Political Science, Old Surgeons' Hall, High School Yards, Edinburgh EH1 1LZ, UK
[b] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds LS29 9HH, UK

ARTICLE INFO

Article history:
Received 27 April 2012
Received in revised form 13 September 2013
Accepted 9 February 2014
Available online xxxx

Keywords:
Socio-technical systems
Sustainability transitions
Energy distribution
Infrastructure governance
Low carbon transition

ABSTRACT

This paper seeks to uncover and examine the complex set of governance challenges associated with transforming energy distribution networks, which play a key enabling role in a low carbon energy transition. We argue that, although the importance of such infrastructure networks to sustainability and low carbon transitions in the energy, water and mobility sectors is clear, there is relatively little understanding of the social and institutional dimension of these systems and appropriate governance strategies for their transformation. This may be because the prevalent model of infrastructure governance in the energy and other sectors has prioritised short term time horizons and static efficiencies. In this paper we draw on the social shaping of technology literature to develop a broader understanding of infrastructure change as a dynamic socio-technical process. The empirical focus of the paper is on the development of more flexible and sustainable energy distribution systems as key enablers for the UK's low carbon transition. Focusing on electricity and heat networks we identify a range of governance challenges along different phases of the 'infrastructure lifecycle', and we draw lessons for the development of governance frameworks for the transformation of energy infrastructure more generally.

1. Introduction

It is widely recognised that the energy systems of industrialised countries are unsustainable and require fundamental restructuring. The growing scientific consensus surrounding anthropogenic climate change along with concerns over energy security and fossil fuel depletion have prompted much discussion over the need to accelerate transformational change towards low carbon energy systems [31,32]. So far, in analyses of energy transitions, much of the discussion has centred around supply side issues with the relative merits of different generation options being debated, along with the various institutional barriers to the diffusion of renewable technologies e.g. wind power, biomass and solar [30,64,92]. More recently a smaller number of studies have begun to explore the role of the demand side in the energy transition and implications for the way we use energy in our everyday lives [43,65]. However, there have been surprisingly few studies which explicitly explore the network components of energy systems – the pipes and wires – which have unique technical and institutional characteristics [9,33,56,58].

Similar sentiments have been expressed in a recent special section of this journal on "Infrastructures and Transitions" [57], where the authors argued that across a number of sectors (water, energy, transport) the role of infrastructure networks in enabling or constraining broader sustainability transitions will be crucial. They highlighted the importance of infrastructures, whether they are distributive (energy, water), communicative (mobility) or accumulative (waste management), in acting as platforms which enable more

* Corresponding author at: Science Technology and Innovation Studies, Old Surgeons' Hall, High School Yards, Edinburgh EH1 1LZ, UK. Tel.: +44 131 650 6366.
E-mail address: Ronan.Bolton@ed.ac.uk (R. Bolton).

http://dx.doi.org/10.1016/j.techfore.2014.02.017

sustainable production and consumption practices to evolve [33]. The authors argued however that the stability of infrastructure systems may 'pose a major barrier to achieve desired sustainability transitions' and hence argue the need for a better understanding of the interactions between social and technological drivers for change and stability ([57]: p. 1195).

In this paper we adopt a socio-technical systems approach to analyse the role of energy distribution grids in enabling the low carbon transition in the UK, focusing on the particular governance challenges faced in the electricity and heat sectors. These sectors account for a substantial proportion of UK total energy consumption (approximately 22% and 41% respectively [15]), and along with transport, decarbonising electricity and heat will be key to achieving the UK government's target of at least an 80% reduction in greenhouse gas emissions from 1990 levels by 2050. In a number of respects (renewables integration, system efficiency, demand side management), distribution grids which can integrate new forms of supply and demand side practices in these sectors will be important enablers for a low carbon transition.

Whilst there has been a degree of focus on the technical and engineering challenges of developing more flexible energy distribution networks, particularly in the electricity sector [22,85], the aim of this paper is to focus on the institutional and governance challenges of transforming energy distribution systems. The paper argues that societies need to move beyond the traditional governance model for distribution (and other energy) networks which prioritises short term efficiencies in incumbent sectors (gas and electricity). A more "innovation friendly" governance model is needed to take into account the challenges to be faced at different stages of what we refer to as the infrastructure lifecycle — from early stage development of local networks, through to the transformation of incumbent national grids. We base our argument on insights from literature on the social shaping of technology and socio-technical systems studies and illustrate it using empirical examples of the UK electricity and heat sectors.

The paper is structured as follows: we begin in the next section by providing a brief literature overview and how we seek to analyse the transformation of distribution grids in the UK. Then, in Section 3, we outline the UK's prospective low carbon transition, highlighting electricity and heat distribution systems and their importance as enablers for this. In Section 4 we focus on the specific challenges being faced in the electricity and heat sectors in the UK: the electricity distribution case illustrates the difficulties faced in transforming highly regulated incumbent systems which are locked-in to an established technological trajectory, whilst the heat case illustrates the challenges of developing new infrastructures in more local/urban contexts. In each of the cases, we discuss the roles of a range of actors in the transformation process including government, private network operators, local authorities and the energy regulator. In the final sections we discuss the broader relevance of our analysis for low carbon infrastructure transformation more generally, focusing on lessons and insights for the development of more effective and coherent approaches to infrastructure governance.

2. Framing and understanding governance challenges for infrastructure transformation

2.1. A socio-technical understanding of infrastructure change

Realising the benefits of more flexible and sustainable systems of energy distribution will require an understanding of the nature of the governance challenge in transforming large scale and complex infrastructure systems. In order to do this we draw from and operationalise the socio-technical approach to analysing the dynamics and long term evolution of large scale technical systems such as energy infrastructure. This approach is situated within the wider field of the social shaping of technology, a basic premise being that the transformation of technologies and technical systems is not determined by any scientific, technological or economic rationality, rather there are a wide range of social, political and institutional factors which interact in a systemic fashion to influence their development [48,75,80,95]. The approach seeks to understand and unpack coevolutionary interactions between a broad range of social and institutional factors such as politics, culture, institutional frameworks and the strategies and practices of a range of actors including, for example, utility companies, sector regulators, policy makers, and end users [7,27,37].

In the specific case of infrastructure based sectors such as energy distribution, but also including transport and water, we must also consider a number of specific techno-economic characteristics [26,55] which mean that these sectors in particular 'typically evolve gradually and with only incremental changes along established paths (path-dependency)', and as a result governing structural changes in these sectors will be 'even more challenging than in conventional sectors' [58: p. 115]:

- Infrastructure services are often essential to everyday life and are therefore classed as public utilities or social goods. Systems such as transport, energy and communications produce positive (e.g. economic growth) and negative (e.g. visual and noise pollution) effects which make it difficult to disaggregate costs and benefits into a clear pricing regime.
- Due to the physical and economic characteristics of infrastructure networks, they tend to be natural monopolies, therefore the services they provide are not traded in markets but are subject to some form of influence by the state e.g. through regulation or public ownership.
- Infrastructure networks are large scale and complex technical systems and their successful operation requires the mutual interaction between large numbers of individual components. In order to achieve this technical complementarity, institutional arrangements which coordinate a range of both public and private actors are required [55].

In the sub-sections below, we provide a brief overview of relevant strands of the socio-technical systems literature, and following this we attempt to operationalise key insights to identify and analyse governance challenge in the transformation of energy distribution networks.

2.1.1. Large technical systems

The origins of the socio-technical systems approach can be traced to the early 1980s when a body of literature developed which sought to understand the emergence and long term

Please cite this article as: R. Bolton, T.J. Foxon, Infrastructure transformation as a socio-technical process — Implications for the governance of energy distribution..., Technol. Forecast. Soc. Change (2014), http://dx.doi.org/10.1016/j.techfore.2014.02.017