Energy Strategy Reviews 13-14 (2016) 11–31

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: www.ees.elsevier.com/esr

Regional winners and losers in future UK energy system transitions

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ARTICLE INFO

Article history:
Received 17 July 2015
Received in revised form
19 May 2016
Accepted 9 August 2016

Keywords:
Energy systems
Energy economics
Energy transitions
Energy modelling
Spatial modelling
Decarbonisation

ABSTRACT

This paper demonstrates the integration of institutional perspectives on energy system transitions into formal energy economic modelling. The perspectives of key UK energy system stakeholders have been used to develop three socio-technical narratives of energy system change that are quantified in a 24-region techno-economic model of the country. Implementing these three narratives in the model environment allows their feasibility for meeting climate targets to be assessed as well as articulating their implied sub-national regional outlooks for technologies and investment. The latter elements are discussed in light of the regional socioeconomic and demographic landscape. The study highlights some of the regional political dimensions associated with future investment targeting in the UK energy system. In particular, energy policy decisions may create tensions between the four different UK government administrations as well as raising important questions about regional economic development and how an equitable energy transition can be achieved for all.

1. Introduction

1.1. Challenges for modelling the energy transition

The use of energy economic models by governments and research institutes has come to be deeply embedded in the policy process in many countries [1]. Energy models, in the broadest sense, are employed at multiple scales. Global models are used for exploring the boundaries of human activity within biospherical limits and are central to climate policy assessment under the United Nations Framework Convention on Climate Change [2]. At the level of individual countries, models are used for understanding the potential impacts of state interventions on the economy and on the environment [3,4]. Models are also often applied at the sub-national scale for developing strategic energy options at a regional, urban, or district level [5,6].

Models are valuable tools for thinking about the future when paired with strategic scenario planning activities [7]. Historically the principal uses for energy models included exploring future challenges to resource security and energy affordability, while today, the reduction of greenhouse gas (GHG) emissions adds a third policy imperative [8]. Understanding social, economic and political pathways that can transition different countries towards energy systems that are compatible with a climate stabilised future is a major undertaking for both scientific research and policy design.

The use of energy models faces continual challenges from within and outside the research community. Common concerns include the transparency of the model structure and data [9], the reproducibility of results [10], and whether insights from a cost optimisation approach approximate the dynamics of real-world energy transitions [11]. National scale models are also sometimes critiqued for their aggregate treatment of spatial dynamics that might drive infrastructure development costs [12]. The implied assumption of neoclassical economic rationalism regarding technology selection is also often criticised [13], as is the use of a single representative agent to capture the interaction of multiple real-world actors [14]. Concerns are sometimes raised that the apparent power of models to demonstrate solutions to complex problems leads to false confidence and the magnitude of the transition challenge being underestimated by decision makers [15,16].

The modelling community has continued to respond to these issues over time through important initiatives. Efforts to improve transparency include the development of open source tools and datasets like OSeMOSYS [17] and the founding of groups such as OpenMod (http://www.openmod-initiative.org/). Concerns that models are "black boxes" whose internal workings are poorly understood have prompted development of models that facilitate exploration of parameter uncertainty [18–20], and increased the

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http://dx.doi.org/10.1016/j.esr.2016.08.002
2211-467X/

prevalence of multi-model exercises to expose uncertainties arising from model structure [21,22]. Other notable responses to criticism of model limitations include the development multi-regional models to explore spatial dynamics [23,24], models that reflect the limited foresight of real decision makers [25], and models that incorporate detailed behavioural choice parameters [26–28].

In this paper we concentrate on increasing the policy relevance of energy systems modelling in two key ways. First, we answer some critics of energy systems approaches by demonstrating how the perspectives of societal actors and institutions can be reflected in modelling. This is achieved by adapting three widely used and popular narrative visions of energy system change, developed in consultation with government, business and civil society stakeholders, into a formal modelling environment. Secondly, we demonstrate how using a spatially explicit model with sub-national detail enhances the value of these existing scenarios by enabling the regional implications of energy transitions to be mapped on to the political geography of the real-world system.

1.2. Capturing social and institutional factors in energy modelling

The history of energy transitions shows that while innovation and markets are important factors affecting technological diffusion; governance, political power, and cultural values are also major drivers [29,30]. It is common for energy economic models to operate using abstract representations of decision-making, typically using a single agent to allocate capital on a rational, cost minimisation basis. This serves as a proxy for real-world processes where multiple stakeholders interact, often with conflicting priorities and objectives. Developing approaches that better reflect the influence of actors and institutions in technology pathway assessment is viewed as a core area for the future advancement of energy systems modelling [31,32].

The sustainability transitions community has been exploring the multi-level, actor dependent, co-evolutionary nature of technological innovation and diffusion for several decades [33,34]. Transitions have historically been explored using a number of heuristic frameworks such as the well-known multi-level perspective (MLP) [35,36]. However, these approaches are often acknowledged as being difficult to operationalise for the type of quantitative policy assessment practiced by governments in their search for pathways towards low carbon energy systems [37–39].

It has been suggested that the energy modelling and socio-technical transitions communities may be able to mutually reinforce one another through collaboration. Socio-technical insights have the potential to bring more realism to the unfolding of transitions within models, while in turn, quantitative modelling offers a path for socio-technical perspectives to be incorporated more directly into the policy decision process as well as to have their basic accounting assumptions tested. One suggested approach for such interdisciplinary research is the recent push towards developing formal models of socio-technical transitions in energy [40–42]. Another valid approach is to use existing tools and scenarios and bridge between the different analytical disciplines [43]. This paper takes the latter approach, and explores the integration of energy system modelling with long term scenarios for socio-technical change developed by the UK's longest running energy transitions research community, the Realising Transition Pathways consortium (Section 2.1).

1.3. Exploring spatial implications of energy transitions

The geographical specifics of future energy decarbonisation pathways are important to explore for reasons of political feasibility, societal acceptability, and from the perspective of corporate interests. Spatial detail is crucial for understanding the core aspects of energy planning, such as regional resource availability, the geographical distribution of future demands, and the requirement to build or extend infrastructure networks. Spatiality is also key for understanding the effect of energy transitions on different stakeholders, especially regional actors. Multiple reviews of energy scenario studies call for work to more explicitly link insights to real-world actors as a means of increasing their relevance for policy-making [44,45].

National scale models frequently constrain their spatial representation to a single region, partially due to data availability, but also due to the additional complexity and computational burden of representing inter-regional energy flows at the sub-national level. Sub-national spatial disaggregation in energy economy models remains comparatively rare in the UK, which is the context for our case study (Section 1.4). Notable exceptions include a 2-region MARKAL model for Scotland and the rest of the UK [46,47], and the Energy Systems Modelling Environment (ESME) model of the UK Energy Technologies Institute (ETI) [48], which features in this paper (Section 2.4). Most UK energy decarbonisation studies to date have tended to focus on delivering insights into future energy transitions at the national aggregate level, with the regional outlook for new technologies and infrastructures, and the implications for key stakeholders such as sub-national governments and local communities remaining underexplored.

1.4. UK policy context

While we consider here the case study of the UK, many of the challenges associated with long term energy planning in an era of state decentralisation and increased regionalism apply across different national contexts with diverse energy, environmental, and economic objectives. Political devolution has been called a global trend [49], and continues to be a driving force in many countries which were previously characterised by highly centralised forms of governance, such as Japan [50], Kenya [51], India, Nepal [52], Mexico, and Brazil [53]. Energy transitions themselves are a global issue, with 178 states now signatories to the Paris Agreement on GHG emissions reduction [54], and 164 countries working to achieve national renewable energy targets [55].

The UK is a unitary nation state with four constituent member countries. Three of these countries, Scotland, Wales and Northern Ireland, have semi-autonomous governments with varying levels of legislative and revenue raising power, while the central UK Government in London also acts as the de facto English government. The devolved administrations have significantly increased their autonomy from the central UK Government since their creation in 1999. An increased desire for self-determination and differences in ideological and popular pressures in Scotland have led to significant policy divergence from England [56], a trend which seems only poised to accelerate in future [57]. The Scottish independence referendum of 2014 came close to breaking up the UK as a political entity, and arguably marked the start of a “newly emerging age of disunification” [58].

At the time of writing, the UK is currently experiencing a period of “constitutional flux” where the political relationships between different member countries are being renegotiated [57]. As well as sub-national tensions between the devolved administrations and the central UK government, tensions also exist between the many regions that lie within England, with the future of regional governance at this scale unclear [59]. Despite having no explicit political representation except at the UK level, English regions remain an important element of English civil and political society, with regional identities being particularly strong in areas such as London, the North East, and Cornwall in the South West [60].