



Governing sustainability transitions through business model innovation: Towards a systems understanding



Ronan Bolton^{a,*}, Matthew Hannon^b

^a Science, Technology and Innovation Studies, School of Social and Political Science, University of Edinburgh, Old Surgeons' Hall High School Yards, Edinburgh EH1 1LZ, UK

^b Hunter Centre for Entrepreneurship, Strathclyde Business School, University of Strathclyde, Sir William Duncan Building, Glasgow, G4 0GE, UK

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ABSTRACT

This paper examines the role of innovative business models in the transformation of socio-technical systems. Focusing on decentralised energy technologies, we explore business model innovation in the context of a transition towards a more sustainable energy system. We conduct an empirical study of two Energy Services Company (ESCo) models for the deployment of combined heat and power with district heating (CHP/DH) infrastructure in the UK. Based on these case studies we illustrate the different ways in which Local Authorities develop business models to create and capture value from more efficient resource use and to deploy sustainable technologies. Drawing from systems theories in the business model and socio-technical literatures, we analyse the interfaces between business models, energy infrastructure and institutions. We propose that a systems based approach to the analysis of business models as embedded in their socio-technical contexts can offer new insights into the dynamics and governance of sustainability transitions.

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1. Introduction

A growing body of literature on sustainability transitions is concerned with the long term transformation towards sustainability of socio-technical systems (e.g. electricity, transport, water infrastructure) relied upon to satisfy basic human needs (e.g. warmth, nutrition, mobility) (Smith et al., 2010; Markard et al., 2012). In parallel a related strand of research has focused explicitly on business models and sustainable development, which contains a much stronger firm-level focus, examining how the development and implementation of novel business models can create and capture value from sustainable innovations (Boons and Lüdeke-Freund, 2013). There has in recent years been a growing interest in how these two strands of work might be synthesized to offer insights into how business model innovation could act as a catalyst for system-wide sustainability transitions (Loorbach et al., 2010; Boons and Lüdeke-Freund, 2013; Wells, 2013a; Foxon et al., 2015; Hannon et al., 2013; Lüdeke-Freund, 2013). Situating business models in a broader socio-technical system context and analyzing “the relationships between sustainability... , government policy

and regulation, and innovative business models”, Wells argues, presents: “an important future research agenda” (Wells, 2013b: p. 238).

This paper aims to further advance these efforts by drawing on systems theories in the business model and socio-technical literatures to examine how novel energy business models have been utilised to deploy sustainable technologies. Specifically it examines the ways in which the Energy Services Company (ESCo) model has been used by Local Authorities to develop combined heat and power with district heating (CHP/DH) systems in the UK. The ESCo model is innovative in the sense that it is centered on the efficient provision of energy services as opposed to units of delivered energy, as per the underpinning logic of the incumbent utility model of energy supply (Richter, 2012). Similarly, decentralised CHP/DH systems differ from the incumbent nationwide centralised electricity and gas infrastructure in the sense that smaller scale CHP plants are located close to centres of demand, creating the opportunity to capture waste heat from the thermal generation process and distribute it locally via a network of distribution pipes. The move to a localised CHP/DH system represents a transformation of the current configuration of the socio-technical system, which the novel ESCo model has been used to govern and facilitate.

It has been argued elsewhere that system-wide change rather than the implementation of individual technologies, institutions or business models will be necessary to realise a sustainability tran-

* Corresponding author.

E-mail addresses: Ronan.Bolton@ed.ac.uk (R. Bolton), matthew.hannon@strath.ac.uk (M. Hannon).

sition (Geels, 2004; Bolton and Foxon, 2015). There are however different conceptualisations of ‘systems’ in the business model and socio-technical literatures. From an analytical perspective the novelty of the paper lies in the deployment of three different systems perspectives from across these two literatures to make sense of the relationship between business model innovation and socio-technical change. From the business model literature we draw from Zott and Amit’s ‘activity system’ approach (Zott and Amit, 2010) which views a business model as “. . . a set of interdependent organisational activities” (p. 217), and from the socio-technical systems literature we draw from both Hughes’ large technical systems (LTS) approach (Hughes, 1983) and the multi-level perspective (MLP) (Smith et al., 2010).

What these three approaches have in common is an emphasis on interdependencies and interactions between different system components; but there are important differences, for example in terms of the relative emphasis on actor agency, the materiality of systems and the influence of politics and institutions. Rather than proposing a unified analytical framework, we discuss how the activity system, LTS and MLP approaches illuminate different aspects of the co-evolutionary relationship between business models and socio-technical transitions, and how an understanding of these approaches provides novel insights for the governance of sustainability transitions.

The paper is structured as follows: In Section 2.1 we provide an overview of the socio-technical systems literature, with a particular emphasis on the LTS and MLP perspectives, and following this in Section 2.2 we discuss business model literatures and introduce the activity system approach. In Section 3 we outline our approach to implementing three different systems perspectives and the paper’s methodology. Section 4 presents two case studies of how the ESCo model has been used to deploy CHP/DH systems in the UK, emphasising how this contrasts with the UK’s incumbent configuration of the UK energy infrastructure and markets. In Section 5 we draw out comparisons between the two cases and in Section 6 draw on the business model and socio-technical systems perspectives to analyse the empirical study. In the final section we draw conclusions and discuss the wider relevance of our paper for studies of sustainability transitions.

2. Theoretical background

In this section we introduce both the business model (BM) and socio-technical systems approaches, highlighting key insights relevant to our study. In the socio-technical section we focus in particular on the multi-level perspective on transitions (Smith et al., 2010; Markard et al., 2012) and the literature on large technical systems (Vleuten, 2004). Our overview of the BM literature begins by summarising fundamental insights from the management and strategy fields (Zott et al., 2011), and more recent studies which examine sustainable business models (Boons and Lüdeke-Freund, 2013).

2.1. Socio-technical approaches

2.1.1. Transitions and the multi-level perspective

Scholars in the field of socio-technical systems and sustainability transitions are concerned with the transformation of technical systems, such as the supply of electricity, gas and water to consumers or the provision of housing and transport (Steward, 2012). The core unit of analysis is the socio-technical regime which is composed of various actor groups, institutions and infrastructures aligned around the secure and predictable delivery of a particular societal function, such as heating, shelter or mobility. Drawing on earlier insights of evolutionary economists (Nelson and Winter,

1977), Rip and Kemp (Rip and Kemp, 1998) view regimes as constitutive of cognitive routines, search heuristics and engineering practices aligned around a particular dominant design (e.g. the internal combustion engine), which span firms and sometimes industries. Subsequently Geels broadened this framing to encapsulate a wider range of social groups, including suppliers, users, and public bodies, with regimes as “the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems” (Geels, 2011: p. 27).

The transition from one regime type to another involves a fundamental reordering and realignment of both the social and technical components of systems. Systems are viewed in dynamic co-evolutionary terms, the causal interactions between actors, institutions and material infrastructure shape system change. In transitions studies this is framed in terms of a ‘multi-level perspective’ (MLP) (Geels, 2002) which theorises change as a dynamic within and between three levels – niches, regimes and landscapes. These are delineated by their degrees of socio-technical structuration. Meso level regimes, as outlined above, are highly structured and established alignments of actors, institutions and technologies. Incumbent actors can modulate co-evolutionary dynamics in line with their own capacities and interests; innovation is managed and predictable, with incremental change along a relatively well defined technological trajectory. Micro-level niches, on the other hand, are spaces where socio-technical interactions are less well structured, thus more radical innovations are possible. Activities in niches and regimes are influenced by an external ‘landscape’, which is largely beyond the control of the system actors, e.g. climate change and globalisation. Given the right landscape conditions, radical niche innovations can begin to influence and potentially overthrow dominant regimes. ‘Transition pathways’, which vary depending on the nature and timing of interactions between these levels, have been developed by Geels and Schot (2007).

2.1.2. Large technical systems

This MLP approach sits alongside earlier work of historians of large technical systems (LTS). Most notable and relevant is the work of Thomas Hughes whose history of electricity infrastructure charted the emergence of highly integrated and centralised systems from their earlier origins as fragmented localised networks (Hughes, 1983). Hughes argued that centralised energy infrastructure was achieved through the alignment of artefacts – technical (e.g. generation facilities, distribution network) and non-technical (e.g. energy companies, laws and regulations) system components. This alignment around a shared system goal, such as optimising the utilisation of large hydro and thermal electricity generators, is achieved by ‘system builders’.

System builders are central to the LTS analysis. They construct systems by breaking down previously well demarcated boundaries between scientific knowledge, technologies, institutions, users etc., enabling interactions to become increasingly fluid and systematised – Hughes referred to this as a ‘seamless web’ (Hughes, 1986). In Hughes’ words “One of the primary characteristics of a system builder is the ability to construct or to force unity from diversity, centralization in the face of pluralism, and coherence from chaos” (Hughes, 1987: p. 52). Inventor-entrepreneurs, financiers and managers are influential during different phases of a LTS, their relative influence depends on the nature of problems that need to be addressed to expand a system, whether technical, organisational or financial. Hughes referred to such system challenges as ‘reverse salients’ (Hughes, 1979). Once these have been overcome systems acquire ‘momentum’ and grow by drawing in resources from and influencing their environment.

2.1.3. Reflection on socio-technical approaches

As the MLP and LTS approaches each view systems as integrating social and technical components they offer broadly complementary perspectives on long term socio-technical change (Bolton and Foxon, 2015). There are differences however: the MLP, with its framing of niches, regimes and landscapes, draws attention towards multi-level patterns and evolutionary based mechanisms of change. Recent reflections have acknowledged the limits of this highly aggregated approach and called for more explicit attention to agency and to political, rather than evolutionary, dynamics (Meadowcroft, 2011; Shove and Walker, 2007). In contrast the LTS tradition brings actors to the fore in the form of ‘system builders’. The focus here is how a system builder, operating in a particular context, constructs a seamless web by configuring a technical system which is synergistic with and achieves traction within a particular social and political environment. In Section 3 we draw out these similarities and differences and outline how both the MLP and LTS perspectives can be deployed to analyse the relationship between business models and socio-technical systems.

2.2. Business model research

The literature on business models is broadly concerned with the ways in which firms organise themselves in order to create and appropriate value from their core activities. According to Osterwalder and Pigneur, a business model is “the rationale of how an organisation creates, delivers and captures value” (Osterwalder and Pigneur, 2010). Teece (2010), sees a business model as “a conceptual rather than financial model of a business” that “articulates the logic and provides data and other evidence that demonstrates how a business creates and delivers value to customers” (p. 173). In their overview of the field, Zott et al. (2011) identify a number of sub topics in the vast and expanding literature; for example studies of online or e-business models, the relationships between business strategy and value creation, and the role of business models in technological innovation.

Alongside the business model concept and its characterisation, the role of business models in commercialising technological innovations has been emphasised. Chesbrough (2010) explains that “the economic value of a technology remains latent until it is commercialized in some way via a business model”. His analysis of Xerox identified a tendency for large firms to select innovations which fit with the prevailing business model. Similarly Bohnsack et al.’s (2014) study of the automotive industry and the adoption of electric vehicle technology identified path dependencies in business model design. Here incumbent firms were willing to change their revenue/cost model and value network, but they were reluctant to change radically their basic value proposition. Björkdahl’s study on how three mechanical engineering firms integrate ICT into their existing processes indicates that even in mature industries accompanying changes to business models are required in order to appropriate value from new technologies (Björkdahl, 2009).

In recent years the links between business models and sustainability have begun to be explored (Schaltegger et al., 2015; Stubbs and Cocklin, 2008; Wicks, 1996). In their overview of this emerging literature Boons and Lüdeke-Freund (2013) identify the intersection between business models and sustainable innovation as a research gap and argue that the business model literature can provide important insights on market introduction and revenue generation with respect to sustainable technologies. Focusing on the energy sector, Wüstenhagen and Boehnke (2008) highlight specific structural features – capital intensity and the power of incumbents – and argue that “appropriately designed business models are an important opportunity to overcome some of the key barriers to the market diffusion of sustainable energy technologies” (p.76). The literature emphasises the potential for business

models which create and capture value from the efficient utilisation of resources – these service-based business models are sometimes referred to as *product-service systems*. A host of examples of potentially sustainable service-based business models have been discussed in the literature, not least in the transport sector where a variety of car-sharing, car-pooling, rental and pay per mile schemes have been developed (Williams, 2007).

2.2.1. The “activity system” approach

How firms create and capture value is the overarching theme of the various business model approaches discussed above. Much of the research is conducted at the organisational level, with in-depth case studies of firms and their business model design.

Zott and Amit present an alternative conceptualization of a business model as “a system of interdependent activities that transcends the focal firm and spans its boundaries”, what they term an “activity system” (Zott and Amit, 2010). What distinguishes their approach from more firm-centric accounts is the conceptualization of a business model as a set of interdependencies and transactions between a focal firm and “its multiple networks of suppliers, partners and customers”. Business model design involves the weaving together of the key components of an activity system – content, structure and governance: *Content* refers to the selection of activities to be performed; *structure* refers to how the activities are linked together and in what sequence; *governance* relates to the parties that perform these activities. Business model innovation “can consist of adding new activities, linking activities in novel ways or changing which party performs an activity” (Amit and Zott, 2012: p. 41).

In the following section we propose that this system-based approach to business models analysis can be situated alongside the socio-technical approaches as a useful basis to analyse the interfaces of business models and their socio-technical context.

3. Analysis at the interface of business models and socio-technical systems

3.1. Deploying three systems approaches

In this section we discuss in more detail the three systems approaches identified in the section above – MLP, LTS and the activity system – and how we propose to deploy them in order to analyse the relationships between innovative business models and socio-technical change.

The core commonality across the three perspectives is that they are system based in the sense that they examine interactions and interdependencies between a range of components which leads to some form of output. In the activity system the creation and capture of value for a focal firm and its partners is the key system output, whereas in socio-technical approach the growth of the technical configuration and its resilience against technological, economic or political uncertainty is key. Also, different types of interacting components are emphasised; for example, the LTS and MLP view a system as socio-technical, i.e. they include technical artefacts, whereas an activity system is primarily composed of transactions between firms. Also, unlike the activity system, the LTS approach and the MLP incorporate politics and institutions into the system. The LTS and activity system approach share a commonality in that they both foreground the influential actors who design or construct the systems, whereas the MLP is more concerned with aggregate dynamics and patterns of transition over longer periods. Table 1 below summarises the basic system idea and the focus of the analysis in each case.

These distinct systems framings offer unique insights into the relationship between business models and socio-technical systems.

Table 1
Summary of systems theories.

Approach	Basic system idea	Focus of analysis
<i>Activity system</i>	Business model as a set of activities linked by interdependencies and transactions between the focal firm and partners	How a manager or entrepreneur designs the content, structure and governance of the activity system to create and capture value
<i>LTS</i>	LTS as a seamless web of social and technical components orientated around a system goal	How system builders at different phases of system change overcome reverse salient to construct and maintain a seamless web
<i>MLP</i>	Niche, regime and landscape as different levels of socio-technical structuration	The shift from one ST regime to another as an outcome of interactions between niche, regime and landscape levels

As such, this paper does not aim to develop an integrated systems framework that synthesizes these different approaches but instead considers their distinctive contribution to a better understanding of innovative business models and socio-technical change. Following an overview of the methodological approach and empirical study, in Section 6 of the paper we return to these analytical frameworks and reflect on the contribution of each.

3.2. Methodology

To mobilise the analytical frameworks outlined in Section 3.1 an empirical study was conducted into how the ESCo business model has been employed to deliver CHP/DH schemes in the UK. Here we outline and justify the overarching research strategy before offering a more detailed discussion of the research methods employed.

3.2.1. Overview of empirical research strategy

We frame the empirical investigation as a case study of business model and socio-technical system interaction and argue that a case study approach offers a useful methodological approach to addressing our research questions. For instance (Yin, 2009) explains that a case study approach is suitable when “(a) ‘how’ or ‘why’ questions are being posed, (b) the investigator has little control over events, and (c) the focus is on a contemporary phenomenon within a real-life context” (p.2). We argue that this research fulfils all these criteria. Additionally, rather than isolating particular variables, context and complexity can be incorporated through a case study approach (Flyvbjerg, 2006). As such case studies have been identified as a powerful means of developing theory (Flyvbjerg, 2006).

The study relied primarily on qualitative data in the form of expert interviews and document analysis. In total 53 semi-structured stakeholder interviews were conducted between June 2010 and February 2012, each lasting approximately 1 h. Quantitative methods were seen as inappropriate for this research, firstly because there is currently very limited information on the numbers and types of CHP/DH schemes in the UK and whether or not ESCos are being deployed.¹ Secondly, quantitative research typically seeks to operationalize and test existing theory, which requires hypotheses to be rigidly defined prior to empirical investigation (Pidgeon and Henwood, 1997). Considering that there has been little research into the interplay between novel business models and socio-technical systems, it is deemed inappropriate to test hypotheses without exploring their relationship first through empirical studies which can provide the necessary insight to generate tentative theory (Weiss, 1994).

¹ Only recently has the UK Department of Energy and Climate Change (DECC) begun to quantify the number and size of district heating schemes in the UK. DECC has contracted the research agency Databuild to survey the sector, but this research had not been published in final form at the time of writing.

3.2.2. Data collection, sampling, analysis and limitations

The research was conducted in two phases. Phase one involved a high level overview of the energy socio-technical regime in the UK, focusing on the role of CHP/DH and ESCos in wider low carbon energy policy and heat decarbonisation strategy. Phase two involved two in-depth case studies of ESCos in different parts of the country where CHP/DH has been deployed.

For phase one, the system level study, an initial round of 46 interviews were conducted which took a predominantly “system” or “sectoral” level analysis (see Appendix A). The main purpose of these interviews was to gather views on the challenges and opportunities for greater ESCo and CHP/DH deployment in the context of the UK’s low carbon energy transition. We wanted to develop an understanding of the ESCo, not as a standalone entity, but one which is embedded in a wider energy regime of public and private actors, governance institutions and infrastructure systems. An initial purposive sampling strategy was adopted where, based on the initial document review of key policy and industry documents, individuals were invited for interview who possessed a strong understanding of ESCo operation, either in an operational (e.g. provision of financial, technical or legal expertise) or strategic capacity (e.g. design of ESCo related policy). Subsequently a snowball sampling strategy was employed, whereby interviewees gave names of further appropriate interviewees (Black, 1999). On the basis of this a wide variety of primarily energy industry and policy stakeholders in the UK were invited for interview.

Phase two involved in-depth case studies of two specific UK based ESCos: Thameswey Energy Limited (TEL) in Woking and Birmingham District Energy Company Ltd (BDEC). These two cases were selected for the following two reasons. Firstly, on the basis of theoretical sampling in relation to ESCo governance; TEL is controlled by the Local Authority but BDEC is controlled by a private operator, and secondly for pragmatic reasons; the authors had good access to the individuals closely involved in developing these ESCos. Seven interviews were conducted across the two cases which focused on the history, structure and operation of the ESCos and were designed to uncover the content, structure and governance of the models and interactions with the wider energy regime where relevant. Three of the interviews were for the BDEC case, one with a senior member of staff at the Local Authority’s Energy Management and Urban Design department and two with separate individuals in the private company who operates the ESCo. For the TEL case study, the authors both interviewed the Chief Executive of Woking Borough Council and the Managing Director of Thameswey Group, but 18 months apart. This offered some perspective on ESCo operation in a changing socio-technical context. These interviews were the main source for the ESCo cases. Appendix B contains a list of those interviewed for each case.

After each interview was completed it was transcribed by the respective authors before being analysed. This involved using the analytical frameworks to categorise the interviews and explore emerging themes. Both sets of interviews were supplemented by documentary analysis of publically available reports, which provided further underpinning evidence that could be used to tri-

angulate the outputs from the interviews. The relevant publications are referenced wherever they have been used as evidence. Since the last of these interviews were conducted in 2012 there have been a number of major policy developments in this area, in particular the publication of a government strategy for heat decarbonisation (DECC, 2012, 2013). These and other contemporary policy documents are also drawn upon.

Through comparative research, and the collection of multiple sources of data (interviews, review of industry and policy documents) at multiple levels (business model and system), we aim to improve the reliability and validity of the study. We recognise however that our qualitative case study approach has its limitations. Our results cannot be quantified and benchmarked against other studies in a direct way and our findings are quite specific to the UK context. It is therefore inappropriate to draw generalizations from the outputs of this study – we do not claim that our findings are directly relevant to all business models, technologies and socio-technical systems. Instead, the empirical investigation constitutes a qualitative exploratory study, intended to provide insights into the relationship between a novel business model (i.e. the EScO model) and a sustainability transition (i.e. shift towards a sustainable, decentralised energy system in the UK). Given these methodological limitations we present a number of recommendations in the conclusion for future work that could complement and expand upon the research presented in this paper.

4. Empirical study: CHP/DH deployment through the EScO model in the UK

4.1. The socio-technical and energy governance context

In the post-war period the UK has developed a highly centralised model for delivering heat to domestic and commercial premises. Partly enabled by the availability of relatively cheap and abundant supplies of natural gas from the North Sea, the UK government and the then publically owned gas industry invested heavily in the national gas grid infrastructure which replaced the previous fragmented gas industry based on manufactured, or town gas (Arapostathis et al., 2013). Throughout this period a major programme of boiler replacements and appliance conversion to utilise the new supply source took place in domestic premises. This transition, which primarily took place during the 1960s and 1970s, was characterised by high levels of centralised control, managerialism and coordination between industry and government actors. Throughout the 1980s the UK privatised its energy industries and introduced liberalisation reforms which saw the break-up of the vertically integrated industry structure (Helm, 2003). By opening up access to the transmission and distribution networks, markets for electricity and gas supply were introduced in the UK. Private utility companies now procure electricity and gas on the wholesale markets and compete against each other to supply customers. However, these institutional changes have had little impact on the way in which heat is supplied.

Today heat in the UK is predominantly supplied via gas; delivered to consumers via a national distribution and transmission network and converted into heat via gas boilers. In 2013 gas accounted for 77% of commercial and residential heat supply, with the remainder being made up of electricity (12%), oil (7%), bioenergy and waste (2%), solid fuel (1%) and heat sold via district heating normally run as combined heat and power (CHP) plants (1%). Important to this study the latter has had a comparatively low-level of deployment with 2000 heat networks serving only 210,000 dwellings and 1700 commercial and public buildings across the UK (DECC, 2014).

The CHP district heat approach is considered to offer a 28% primary energy saving compared to when electricity and heat are

generated in isolation from one another (Carbon Trust, 2010). This is because heat is captured rather than lost via cooling towers, and by operating on a district-scale, electricity transmission and distribution losses are reduced because it is generated so close to the point of consumption (Carbon Trust, 2010). Despite this advantage CHP district heat schemes have struggled to proliferate in the UK. The highly centralised organisational structure of the energy industries (both electricity and heat) have meant that local level actors have historically been unable to “capture” this value in economic terms and create the investment case for CHP/DH infrastructure (Bolton and Foxon, 2013). Russell’s study of CHP/DH during the pre and post war periods in the UK cites the dominance of “producer interests” and a set of rules and institutions governing the operation of energy industries which made it difficult for small scale generators to input into the national electricity system and to create local markets for heat supply (Russell, 1993).

One of the reasons cited for the low penetration of CHP/DH has been the challenges that CHP generators face in selling electricity into the national wholesale electricity markets. For CHP plant owners the transactions costs are extremely high and these smaller scale generators face penalties if they fail to generate the contracted amount at a particular point in time, substantially increasing operational risk. Another key reason cited is the lack of local level financial capacity and energy planning expertise to develop the infrastructure required to distribute the heat locally. Contrasts are often made between the centralised UK model with other European countries, such as Denmark and Sweden, where the organisation of heat supply is more fragmented and there has historically been a higher degree of control exerted over energy distribution infrastructure by local and municipal actors (Hawkey, 2014).

There are however signs that the UK’s heat sector is about to undergo a period of change, driven by concerns around climate change, energy security and affordability. Focusing on the first of these, the UK government committed to reducing greenhouse gas emissions by 80% from 1990 levels by 2050 as part of the 2008 Climate Change Act. Whilst most sectors are expected to undergo a radical transformation there is a general consensus that achieving this target is incompatible with the current status of the UK’s building heat supply sector (Eyre and Baruah, 2015). District heating is envisioned to play a more important role in the future as part of the UK’s low-carbon heat strategy² but there is still a great deal of uncertainty about how its exact level of deployment as numerous other low-carbon solutions are also expected to play a key role; including more efficient gas boilers, electrical heat pumps and building level efficiency solutions (DECC, 2013).

4.2. CHP/DH deployment through the EScO model

EScOs fall into two basic categories; *energy performance contracts (EPCs)* and *energy supply contracts (ESCs)*. In essence ESCs focus on the management of supply and distribution infrastructure and EPCs on the management of end use appliances at a building scale. ESC type EScOs are particularly useful for enabling investment in technologies such as CHP/DH which can improve energy efficiency by reducing the amount of energy input required to deliver a particular service such as lighting or space heating. But EScOs are not specific to CHP/DH; elsewhere it has been outlined how the model is currently being utilised in the UK to deploy a range of supply and demand side technologies which deliver returns from energy efficiency in different ways (Hannon and Bolton, 2015;

² In its 2013 Heat Strategy the Department of Energy and Climate Change (DECC, 2013) highlighted the role of district heating infrastructure in contributing to this overall effort; referencing a consultancy report by Pöyry, DECC proposed that ‘up to 14% of the national heat demand could be served by heat networks’ (p.45).

Hannon et al., 2015). Three broad categories of ESCos have been identified: (1) Local Authority (LA) owned “arms-length” model; (2) private sector owned energy service provider; and (3) community owned and run (Hannon, 2012; Hannon and Bolton, 2015).

The limited literature on ESCos in the UK highlights some of the challenges facing innovative sustainable business models in such a system context. Hannon (2012) and Hannon et al. (2013) explored how ESCos have struggled to proliferate in this context due to a mutually reinforcing relationship between the incumbent energy utility company (EUCo) model, key energy policy and regulatory frameworks and market designs. Hannon notes that despite this model having enjoyed some niche application, not least by LAs and community groups, it has started to have a small but potentially important influence on the wider UK energy system. Examples include changes in regulation to help facilitate ESCo activity, as well as some diversification of the incumbent utilities in reaction to these new value propositions. Recent work by Barton et al. (2015) has added to this debate by exploring how the LA owned ESCo model could help facilitate non-incumbent actors to take the lead in a transition to a low-carbon energy system by acting as the main purchaser of electricity generated by local energy schemes.

Studies evaluating the potential contribution of CHP/DH to the UK’s energy transition typically note that if the technology is to play a meaningful role the involvement of local authorities will be key to overcoming various institutional and economic barriers to deployment (Hawkey et al., 2013). The main reason for this is that CHP/DH schemes need a strong degree of local coordination, and in order for the upfront capital investment to be justified larger schemes involving a significant infrastructure component will ideally have a guaranteed customer base at the start of the project. Local Authorities will typically own and operate a number of large municipal buildings (e.g. offices, libraries, sports centre) and residential schemes in and around city centre areas, which have a high heat demand. These buildings can as such become the “anchor loads” around which a large city scheme can evolve and achieve scale. The initial contract for heat supply between a Local Authority and a potential CHP/DH investor is therefore key and this long term relationship between the supplier and customer of heat defines the business model for the service.

Whilst the model can be used to deliver a range of different energy solutions, such as energy efficiency lighting or roof-top solar PV, LAs have typically used the model to deliver CHP/DH schemes with two common approaches emerging (Hannon and Bolton, 2015). The first can be seen with LAs such as Woking and Aberdeen where they have opted to create their own ESCos which supply heat (and electricity) to LA buildings and sometimes neighbouring commercial and residential buildings: we term this the “arms-length” model. Here the council outright owns or is the majority shareholder in the company, but the ESCo is a separate legal entity from the council. The second approach is where the LA enters into a supply contract with a separate private company: we term this the Energy Service Provider model. This model has been utilised to develop CHP/DH schemes in cities such as Southampton, Leicester, and Birmingham.

4.3. ESCo case studies

In the sub-sections below we present two in-depth case studies of UK LA application of the ESCo model.

4.3.1. Birmingham district energy company ltd

Birmingham District Energy Company Ltd. (BDEC) is a private sector ESCo that generates and distributes electricity, heat and chilled water to a range of customers in and around Birmingham city centre (Cofely, undated). The company operates three separate schemes in the city, each consisting of gas-fired CHP plants, distri-

bution pipes and conventional boilers which are used for “top up”. The schemes are based around clusters of large customers including the International Convention Centre, the Hyatt Hotel, Aston University, the Town Hall and Birmingham Children’s Hospital, and more recently a number of multi-storey council flats. Cofely District Energy (DE) operates the scheme on a concession basis under a long term 25 year contract with Birmingham City Council and operates a number of similar schemes in Southampton, London, Manchester and Leicester. Cofely DE is a small subsidiary of Cofely, the Energy Service Provider arm of the French multinational firm GDF-Suez.

Although established in 2006, the origins of BDEC can be traced back to the 1980s when Birmingham city council faced legal challenges from council housing tenants to improve heating and insulation standards. Although the response at the time was to invest in electric heating, rather than capital intensive CHP/DH, a small pilot CHP plant was installed and following the episode engineers in the energy management department increasingly began to advocate district energy as a long term solution (Hawkey et al., 2013). In 2004, partly motivated by national government programmes for carbon reduction at the local level such as the Carbon Trust’s “Carbon Management Plan” and “The Local Authority Carbon Management Programme”, the energy management department conducted a feasibility study into decentralised energy in the local area. This identified the area around Broad Street, close to the civic and commercial city centre, and Eastside, close to Aston University, as potentially economically feasible initial schemes to be developed. This also coincided with city centre regeneration plans and a boiler retrofit at the national convention centre (Hawkey et al., 2013). Political support for the city to take a leadership role in sustainable energy from the then deputy leader of the council for Birmingham also helped CHP/DH advocates to exploit this window of opportunity.

In 2006 BDEC was formed after Cofely DE (then an independent company called Utilicom) emerged as the preferred bidder for the council’s 25 year contract for the operation of the schemes, the first of which came into operation in 2007. Project finance for this initial scheme with a capital cost of £2million was secured through a grant awarded to the council through the government’s Community Energy Programme and equity finance from Cofely DE. BDEC is formally controlled by Cofely DE but large customers, including the council, are part of a “partnership board” who benefit from an energy rebate funded from their 50% share in BDEC’s profits (Hawkey et al., 2013). As part of the contract Cofely DE and the council entered into a “joint cooperation agreement” where the council actively promotes the development of the scheme within the city, but commercial decisions regarding expansion etc. lie with the company.

Beyond this overarching structure exists a variety of different commercial relationships. For instance, as part of the Broad Street scheme the council directly contracts with BDEC for energy supply, but other public buildings on the Eastside scheme (university & hospital) procure energy from BDEC via an energy supply contract with the council. This enables these customers to bypass stringent public procurement rules, reducing their transaction costs. Broadly, these energy agreements centre on the delivery of low carbon energy at a rate below an agreed baseline for a 25 year period, thus shielding the council and other customers from gas price fluctuations and various other risks entailed with the day to day operation of an energy supply system. The structure of the model, contractual arrangements and the financing approach in this case are outcomes of a risk-averse approach taken by the council through the development of decentralised energy in Birmingham.

Expansion of DE in Birmingham is expected to proceed along similar lines with new schemes being developed on a piecemeal basis, with commercial criteria at the centre of BDEC’s rationale. The council’s strategic vision and catalytic role does have an influ-

ence; future plans involve a more sophisticated zonal approach targeting specific areas of the Birmingham outside the commercial heart of the city centre. The most recent development has been the connection of a number of multi-storey council housing blocks, partly funded through a grant from the Homes and Communities agency's Low Carbon Infrastructure Fund, and future plans include a proposal to install CHP units in new schools across the wider metropolitan area, and the development of a scheme in an old industrial area at the periphery of the city centre. The long term aim is to improve interconnection between the schemes as they expand and eventually link up.

4.3.2. Thamesway energy Ltd

Woking Borough Council (WBC) began engaging with sustainability and energy related issues in the early 1990s with a series of energy efficiency measures to reduce its own energy consumption (Wbc, 2012). By 1999 these initiatives had culminated in the establishment of the Thamesway Group, which operated as an “arms-length” subsidiary of the council. The organisation was established to help the council deliver on its four main priorities of: decent and affordable housing, environmental conservation, health and well-being and finally, economic development (Thamesway, 2012c).

A year later in 2000, Thamesway Group established Thamesway Energy Limited (TEL) as a public-private enterprise specifically to “make long term energy and environmental project investments in support of the Council's climate change strategy” (Thamesway, 2012a). Initially, ownership of TEL was shared between WBC's Thamesway Group and Xergi, a Danish company with expertise in the design and operation of CHP schemes. Xergi owned 81% of TEL, in line with rules at the time which prohibited councils from owning more than 19% of private companies. Whilst WBC are now the sole owners of the ESCo following rule changes, Xergi are contractually responsible for the “building and operation of the energy centres” (Thamesway energy, 2012).

TEL operates as an ESCo, providing heat, electricity and cooling via energy supply contracts to over 170 commercial and domestic customers in the Woking area (Thamesway, 2012b). To date TEL has developed two large CHP schemes in Woking: one in the City Centre and the other at Woking Park, a large out-of-town leisure complex. Some of this infrastructure had previously been developed by the council in the absence of TEL (EST, 2005). In addition to district heating TEL also owns and operates a large number of PV installations throughout the area, such as the PV canopy outside Woking train station.

A key factor in the early formation of TEL was the presence of a small number of strong advocates of CHP/DH across both the engineering and financial departments of the council who were convinced of the competitive advantage offered by more efficient decentralised energy production, and were deeply skeptical of the capacity of incumbent energy utilities to deliver a sustainable energy future. Influenced by these individuals, a combination of both technical and financial innovation has remained a key feature of the Woking scheme, which has been enabled by a supportive and stable local political environment. Throughout its existence TEL has enjoyed consistent local political support, in part because the council's Chief Executive is an Executive Director on the board of Thamesway Group and was one of the originators of TEL in the 1990s.

By establishing a legally separate “arm's length” private sector company, WBC is partly insulated from the financial and technical risk associated with delivering energy service projects. It has also enabled WBC to access private sector finance and expertise, manage its budgets autonomously and to take a longer term perspective outside of the political cycle. WBC provided TEL with its necessary start-up funds, which were drawn from the energy savings

it had achieved on its own properties (Thorp, 2011). Furthermore, it has also meant that it has been able to secure finance through the council at lower than commercial lending rates, via public sector borrowing schemes such as the Public Loan Works Board (PWLB). Additionally it has meant that the council has been able to expand its operations outside of Woking with the establishment of a subsidiary called Thamesway Central Milton Keynes Ltd. who have developed a CHP/DH scheme in Milton Keynes, approximately 100 km away. However, due to the coincidence of this development with the financial crisis, and the increasingly constrained financial climate for councils, WBC has since placed a moratorium on investments in future energy projects outside of Woking.

TEL sells electricity, heat and cooling to a range of commercial, residential customers along with servicing a number of council owned premises in the town. It competes against incumbent energy utilities by using the efficiency gains from its CHP plant to set its customer tariffs at approximately 5% below the going market rates. In doing so, TEL has generated significant sums of revenue that have been channelled to support the wider activities of the Thamesway Group and WBC. For instance, profits from its energy projects have been recycled to help support projects relevant to the council's climate change strategy, having generated approximately £700,000 since TEL's formation.

A notable feature of TEL has been a willingness to experiment with new technologies and ways of organising CHP/DH. In the early 1990s, for example, TEL was an early adopter of roof top solar technology and has since conducted trials on fuel cell installations. The use of private electricity wires which bypass the incumbent electricity distribution networks, and hence charges for using these networks, has also been a feature. The alternative option, trading in the national wholesale electricity market, entails high transaction costs for small scale and less well-resourced operators such as TEL. However, there have been legal questions surrounding the use of private wires and recent regulatory changes have mandated that these operators allow 3rd party access to their networks. This has created a degree of uncertainty around this aspect of TEL's model, however its status as an “energy island” has enabled TEL to maximise revenue from electricity retail sales, and its growing expertise in managing its own electricity system has enabled it to create new sources of revenue by selling flexibility services to the national electricity transmission system operator.

5. Comparison of ESCo activity systems

Drawing on Zott and Amit's framework, in this section we compare the two ESCOs, initially by discussing how they were structured in each case and subsequently by examining the transactions and interactions which shaped the activity systems.

5.1. Structuring the ESCOs

It is clear from the empirical study that the role and configuration of the ESCOs were different in each case and this has led to different approaches to implementing CHP/DH. In helping to explain this in more depth we draw upon the activity system approach (Zott and Amit, 2010) – business model content, structure and governance – to unpack how these differential outcomes are related to the nature of the ESCOs in each case. These characteristics are presented and contrasted in Table 2.

The *content* of the ESCOs (i.e. what activities are performed) were broadly similar, primarily the sale of heat and electricity using CHP/DH infrastructure. The economic rationale of the ESCOs is to capture the monetary value created from energy savings and use it to justify the significant upfront capital investment in CHP/DH infrastructure involved. By examining the founding principles or

Table 2
Summary of ESCo activity system in the two cases.

	TEL	BDEC
Content	<i>Founding principles</i>	Promote council's sustainability objectives, compete with incumbents, trial new technologies and promote decentralised solutions
	<i>Activities</i>	Lower carbon heat, cooling and electricity supply to domestic, commercial and public sector customers
Structure		<ul style="list-style-type: none"> • Electricity sales through private wires, trialing new technologies • Expansion to other cities, willingness to risk and create new demand • Projects judged primarily on the basis of how they feed into an integrated sustainability policy framework
Governance		<ul style="list-style-type: none"> • Long term contract between LA and a private operator • Private ESCo has operational autonomy for the duration of the contract • LA one of a number of stakeholders consulted

social aims of the business models (as emphasised by Boons and Lüdeke-Freund's (2013)) some differences begin to emerge. In the case of TEL, Woking council's objective at the outset has been primarily to promote sustainable development in its broadest sense throughout the locality. In the case of BDEC, its initial aim was less strategic and more commercially orientated. As a result there were different conceptualisations of what constitutes "value", with economic value on the one hand (the project's financial rate of return) and environmental value on the other (the broader conceptualisation of sustainable development).

Unsurprisingly the *structure* of the ESCos (i.e. how their activities are linked and their relative importance) also differed in each of the cases. In the BDEC case, the Local Authority prioritised energy bill reduction and as a result a commercially led, low risk, CHP/DH deployment strategy was adopted. This is resulting in a piecemeal and fragmented pattern of infrastructure development where buildings with a large demand for heat are prioritised. Also, the ESCo and the CHP/DH programme is largely a stand-alone activity with little interaction between it and other sustainability initiatives across the locality. In the TEL case, on the other hand, WBC was more interested in how the ESCo could support a wider programme of environmental sustainability across the locality. Its activities are therefore embedded in a larger organisation, and because of this the commercial constraints on its activities have not been present to the same extent as in the BDEC case. The developers of this ESCo were extremely skeptical of incumbent actors and felt that their core activities were best achieved as an autonomous organisation, exemplified for instance by investment in a private wire electricity infrastructure to bypass the incumbent electricity network and market.

The third dimension of Amit and Zott and Amit's activity system is its *governance* (i.e. who performs the activities). The key difference across the two cases was the focal actor who coordinates other actors and makes operational and strategic decisions. In the TEL model the Local Authority is the focal actor that owns and finances the "arms-length" ESCo. In this sense, while it is a separate legal entity and the ESCo enjoys some autonomy, it is ultimately answerable to the local council. In contrast the BDEC case is more complex. The private operator, called the energy service provider (Cofely), creates a project specific special purpose vehicle (SPV) ESCo (BDEC) but does so on the basis of a long term supply agreement with the LA. While the LA is a key customer and an important stakeholder, for the duration of this contract it seeds control of the ESCo to the private operator who becomes the focal actor.

The key dimensions of the ESCo activity systems in each case are summarised in Table 2. From an analysis of the cases we can see how the link between the business model content, structure and governance played out in different ways. The lineage between the initial aim, or founding principles, the prioritisation of social, environmental or commercial goals, and the degree to which public authorities or private companies are the focal actors is key to shaping sustainable business models. Business model activity systems are then formalised in contracts, in or cases between LAs, customers and private operators.

5.2. The ESCos and transacting partners

In the second part of this analysis section we turn to the relationship between the focal actor and a wider set of transacting partners relied upon to construct and maintain the activity system.

There are important resources that have been required to create and sustain the ESCo activity systems which, for different reasons, are typically sourced externally. Below we summarise three different types of external resources which were particularly important to the ESCos and which were not readily available to the focal actor.

5.2.1. Finance (key actors: national government, banks)

As Wüstenhagen and Boehnke (2008) note, a characteristic of the energy sector is capital intensity. The scale and long term nature of investment in energy and other infrastructure assets such as pipes and wires, CHP plants etc., means that much of the investment risk is upfront, implying a heavy reliance on debt capital from external sources such as banks. The way in which the business model for new infrastructure is structured has a key role to play in determining the both the willingness of external investors to finance CHP/DH and the cost of capital, which greatly influences the economic viability of a scheme.

We notice that in both cases the approach to investment risk was politically mediated. In the BDEC case this was achieved through the agreed long term contract between the private operator and the LA. In this case the operator has rights to operate and potentially expand the scheme in the city according to its commercial criteria. The Local Authority was risk averse and as a result opted for an arms-length model where financing of the infrastructure investments is at commercial rates of return.

In the TEL case the council lent funds directly to the ESCo via the national Public Works Loan Board, offering it a low interest loan. Political control is more direct and, as we can observe from its failed expansion, the success or failure of the business model is

much more dependent on this institutional support. The advantage of this however is that the ESCo is less constrained by short term commercial criteria.

5.2.2. Access to markets (key actors: incumbent utilities, market intermediaries)

In our ESCo cases we saw both a process of market creation through the development of new heat supply infrastructure but also the need to access external electricity and gas markets. As outlined in Section 4.1 these markets have developed during the 20th century as highly centralised at the national scale with diminishing local influence. Particularly challenging for ESCos operating decentralised generation in this context is to sell electricity into the national markets. In the BDEC case electricity is sold into the existing national wholesale market thus incurring significant transaction costs, but in the TEL case, in order to avoid these costs and to maximise revenues from electricity sales, the ESCo has invested in its own private electricity wires to service a number of its large customers.

5.2.3. Technical expertise (key actors: consultants, specialist energy companies)

The cases illustrate that developing a successful ESCo requires technical expertise of complex energy infrastructure but also knowledge of how to evaluate investment risks and successfully transact in complex energy markets. ESCos such as BDEC may be able to access such expertise through commercial links with large multi-national energy companies. However, more autonomous ESCos typically need to procure such expertise from consultants or enter into some form of a partnership with a specialist technology company. In the TEL case, much of the commercial expertise existed within the council but CHP expertise was provided by the Danish firm which was a shareholder of the ESCo in its early phase.

As has been noted, the ESCos operating in distinct contexts differed in how they drew upon these external resources, they are by no means fixed and other types of external resources may be more important in other types of sustainable business models.

6. Discussion: understanding business models and sustainability transitions – the contribution of systems perspectives

With reference to the three systems approaches this paper adopts – MLP, LTS and the activity system perspective (Section 3.1) – and the results from our empirical study, this section identifies three key insights this research uncovers in relation to the wider relationship between business models and socio-technical change.

6.1. Agency in the market and political spheres

Whilst the MLP approach places more emphasis on processes and mechanisms of change, the activity system and LTS perspectives forefront actors and agency, but in different ways. Zott and Amit's approach emphasises the role of entrepreneurs and managers in creating and delivering returns to the actors which constitute the activity system, including the focal actor but also key partners. This type of agency in the market was evident in how Local Authorities engaged with banks, technical consultants, national government, market intermediaries etc. in order to attract the necessary finance, gain market access and expertise.

However, this does not capture the political nature of system building which is emphasised in the LTS approach. We have seen how underpinning the market transactions in each case have been political frameworks which were particularly important in managing financial risk. Given its large scale, capital intensity and social function, public infrastructure constitutes a highly politicized topic.

As such successfully delivering value through business model innovation in this context is akin to system building where political, economic, social and technical components need to be brought together. This emphasis on the need to consider politics, economics, technology and society as part of a “seamless web” is a key insight of the LTS approach (Hughes, 1986).

The case studies illustrate how a synergistic relationship between a business model, investor perceptions of risk and a political framework is a crucial component of developing a successful energy project. Trade-offs between risk and political control are greatly influenced by the willingness of political actors to commit to a scheme, the budgetary position of the council and the extent to which environmental or economic goals are at the core of the initiative.

6.2. Interaction with incumbent regimes

Looking back at the empirical cases, it seems that whilst CHP/DH deployment via ESCos has a significant local impact, its impact on the structural challenge of decarbonisation of UK heat demand and the wider energy transition is relatively minor. This is unsurprising as socio-technical systems perspectives stress that societal services such as heating, lighting, power etc. are delivered through a complex chain involving interdependent activities such as resource extraction, energy conversion, transmission and distribution to the end customer. Customer facing business models such as ESCos are but one part of this.

In order to evaluate the prospects of business model growth and replication one needs to have an understanding of the wider interactions between infrastructure, institutions and actors that constitute systems. One way of doing this is through the lens of the MLP where innovative niche technologies operate outside the established regime structures but can over time, and with the right level of support, diffuse more widely and be incorporated into regimes or potentially replace them.

The TEL case can certainly be viewed through this lens. Here the retail offering of the ESCo is benchmarked against the incumbent alternative and the ESCo is owned and operated by a non-incumbent player. However, in the BDEC case the picture is more complex as the ESCo contract was awarded to a company which is itself owned by a multi-national energy company i.e. an incumbent player. This case cautions against a simplistic reading of the MLP narrative with regard to business models i.e. where innovative business models are framed as niches struggling against incumbent regimes. Rather it supports Bidmon and Knab's contention that innovative business models act as translation devices between niches and regimes (Bidmon and Knab, 2014). Furthermore, our study suggests that both new entrants and incumbent players utilise business models to commercialise niche technologies (Schaltegger et al., 2016).

Based on our case studies two possible future pathways for ESCos and decentralised energy to achieve scale and replication in the UK can be identified. The first follows the TEL approach where the business model enables local actors to become increasingly autonomous from the incumbent regime, for example through the development of localised infrastructure and markets. An alternative to the competitive/autonomous logic is closer to the BDEC model where the business model is more closely aligned with the existing market based logic of the system and more closely controlled by incumbent actors. The former is clearly more disruptive, both in terms of institutions and infrastructure, but may be more difficult to standardise and replicate as it requires significant entrepreneurial activity and risk taking on the part of the Local Authority. Also, it is likely that in order for this pathway to succeed significant structural changes to the existing socio-technical regime will be required, not least a decentralisation of decision making and

a radical overhaul of the current centralised market and regulatory framework of the energy system.

The study is therefore inconclusive as to the most appropriate business model for accelerated CHP/DH in the UK, whether it is an adapted version of the existing regime logic – what Winskel and Radcliffe term “continuity-based” change (Winskel and Radcliffe, 2014) – or a niche based/disruptive pathway. With the strong political support of the Local Authority TEL was able to develop systemic solutions and challenge the incumbent regime, for example by developing its own private wire links and bypassing incumbent electricity markets. However outside of the supporting political environment, this proved to be more challenging; when the attempt to replicate the model outside of the Woking Borough area failed the council placed a moratorium on further expansion in order to avoid further financial losses. The lower risk BDEC model would appear to be more amenable to replication in new contexts as it is more in line with existing regime practices of market-led system development.

6.3. Achieving alignment

Based on our engagement with the three systems approaches we suggest that a useful way of conceptualising the relationship between business models and sustainability transitions is through the alignment of activity and socio-technical systems. Successful business model entrepreneurs, or managers, act as system builders by entering into partnerships to draw on resources, such as finance and technical expertise, and construct a seamless web of technological, political, economic and social components. The challenge is to align content, structure and governance of the business model with the evolving socio-technical context, incorporating dynamic changes to regime structures (e.g. energy markets and utility business practices) and the political framework within which decisions are made.

The activity system perspective is a particularly useful framework for understanding how a business model is constituted through interactions between market actors; however, the LTS and MLP insights are required to understand the political and structural dimensions of a wider co-evolutionary dynamic within which market actors are embedded.

7. Conclusion

This paper set out to investigate the relationships between business model innovation and socio-technical transitions to sustainability. The paper's objective was to illustrate how different “systems thinking” approaches can offer alternative perspectives on the dynamic between innovative business models and socio-technical system change. Drawn from the business model and socio-technical literatures, three systems approaches (*activity systems*, *large technical systems (LTS)* and *the multi-level perspective (MLP)*) were applied to the empirical case study of Energy Services Company (ESCO) and combined heat and power with district heating infrastructure (CHP/DH) deployment in the UK to demonstrate how these perspectives illuminate different aspects of the relationship between business models and socio-technical change.

ESCO business model's returns are based on energy efficiency gains rather than unit sales and delivered via decentralised technologies such as CHP/DH; an approach that stands in stark contrast to the incumbent energy utility model of centralised energy supply. Through an in-depth analysis and comparison of two specific ESCO cases we identified areas where these systems approaches provide distinct insights.

The activity system and LTS approach forefront actors and agency in constructing systems, but in different ways. For example, the activity system approach places the emphasis on entrepreneurs and managers who enter into market transactions to shape the content, structure and governance of a business model in a way which delivers economic value. The LTS approach on the other hand views system builders as engaging in a political process through which choices about technology deployment are made. Through the case studies we highlighted the different ways in which business model developers interact in both the market and political spheres, thus expanding on the firm-centric conceptualisation of agency in the business model literature.

Socio-technical approaches forefront the materiality of systems, with the MLP emphasising to a greater extent than the LTS approach their structural aspects and rigidities. These theoretical lenses direct attention to the broader coevolutionary dynamics in which business models are embedded. Particularly important in our cases were the relationships between business models, political frameworks and infrastructure systems at the local and national scales.

Our main contribution has been to emphasise the differences and similarities between systems approaches and their relative strengths and weaknesses in accounting for the dynamic relationship between business models and sustainability transitions.

The shift from unsustainable to sustainable socio-technical regimes will involve a realignment of system components around a new conceptualisation of value, but as the example of CHP/DH in the UK illustrates, in the absence of deeper reforms of political, regulatory and market structures, it is likely that business model innovation in and of itself will be insufficient to enact such a system change. We argue that an understanding of synergies and alignments of activity and socio-technical systems is a fruitful way of conceptualising the challenge of governing sustainability transitions through business model innovation. ESCOs for CHP/DH in the UK have yet to achieve this alignment and until they do it is likely to remain as a niche technology.

In terms of future research we note that our study was limited in that it focused on innovative or emergent business models, rather than established ones. Building on recent research on the role of incumbent firms and business models in sustainability transitions (Wells and Nieuwenhuis, 2012; Geels, 2014), further research could analyse in-depth the activity systems of these firms and how they create positive feedbacks with dominant socio-technical regimes.

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Appendix A. Sector level interviews

See Table A1

Table A1
List of interviews.

Organisation type	Position	Date
Local Authority	Head of environment unit	July 2010
	Sustainability/energy manager	July 2010
	Principal designer & energy engineer	Aug 2010
	Director of environmental services	Aug 2010
	Energy manager	Aug 2010
	Principal designer & energy engineer	Aug 2010
	Director of sustainable development	Sept 2010
	Head of sustainable development	Sept 2010
	Head of sustainable development	Oct 2010
	Head of decentralised energy delivery	March 2011
	Chief executive	Jan 2012
	Sustainability project manager	Sept 2010
	Private sector energy supply contracting ESCo	Director
Director		Aug 2011
Knowledge transfer partnership associate		Jan 2012
Private sector energy supply contracting ESCo (Energy Utility owned or division of an Energy Utility)	Services manager	June 2010
	Head of Community Energy	Oct 2010
	Head of community energy	March 2011
	Director of community energy	Sept 2011
	Product development and energy services manager	Sept 2011
	Business development director of community energy	Sept 2011
	Business development director of community energy	Jan 2012
	Head of energy solutions	Jan 2012
	Business development manager of community energy	Jan 2012
	Senior business manager commercial energy division	Jan 2012
Community owned and run ESCos	Committee member	July 2011
	Committee member	Aug 2011
	Committee member	Feb 2012
	Committee member	Feb 2012
	Accountant	Feb 2012
Consultancy or 'think tank'	Consultant (low carbon and local energy systems)	July 2010
	Associate Director (low-carbon)	Jan 2011
	Partner (low-carbon agriculture)	July 2011
Government department	Chief economist and Head of Fair markets (consumers)	Oct 2011
	Deputy Head of community-led policy making (energy)	Aug 2010
	Head of new business and economics (housing)	June 2010
	Policy Advisor (energy)	Aug 2011
Trade association	Deputy Director (interest in district energy)	Dec 2010
	Senior policy officer (interest in local government)	August 2010
Law firm	Associate (interest in district energy)	July 2011
	Partner	July 2011
Investment firm	Partner	Aug 2011
	Head of New Energy and Power Research	Sept 2010
University	Director of Sustainable Energy Finance	July 2011
	Senior Research Fellow – University	Sept 2010
Regional Development Agency	Head of Environment & Project Leader of Energy Services Procurement Framework	Aug 2011

Appendix B. List of case study intervieweesSee [Table A2](#)**Table A2**
Case study specific interviews.

Case	Position	Date
TEL	Chief Executive	10/06/2010
BDEC	Commercial Manager	28/06/2010
BDEC	Sustainability Manager	16/07/2010
TEL	Managing Director	19/07/2010
TEL	Chief Executive	10/01/2012
TEL	Managing Director	11/01/2012
BDEC	Emergent Technology Specialist	21/07/2011

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