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Emerging energy transitions: PV uptake beyond subsidies

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ABSTRACT

In the past decade there has been a substantial increase in the uptake of residential solar photovoltaic (PV) systems globally, which is starting to impact upon traditional electricity systems. An emerging energy transition is being driven by actions taken by actors at the grassroots level, and enabled by declining technology costs and new niche business models. However, to date, most work exploring change in energy systems has tended to focus on technological innovation and economic processes, leaving social aspects and daily activities under-addressed. Similarly, most theories that consider individual behaviour have tended to neglect the wider system of change. This paper presents an approach for simultaneously exploring behavioural and systemic change and demonstrates its use in a case study of PV uptake in New Zealand. The Energy Cultures framework is used alongside the Multi-Level Perspective of socio-technical transitions to examine the broad range of factors driving, shaping, and constraining PV uptake, and the interactions between global and national landscapes, the socio-technical regime within which users are taking action, and the niche opportunities emerging. Taking an integrating approach allows these perspectives to be brought together, providing valuable insights as to how adoption might be promoted or constrained, and the implications this may have for the future management of electricity grids.

1. Introduction

PV uptake, particularly when it occurs in dense pockets, challenges the traditional socio-technical electricity regime. Rather than energy being generated in centralised power stations and distributed to end-users, households that have PV are using less centrally generated electricity and some are using it in different ways (Keirstead, 2007; Bahaj and James, 2007; Dobbyn and Thomas, 2005; Erge et al.; 2001; Haas et al., 1999). High levels of adoption are starting to shift electricity market dynamics (Rhys, 2016) as well as raise concerns around social equity (Macintosh and Wilkinson, 2011) due to the high costs associated with the technology making it largely prohibitive for many. Therefore, advancing our understanding of the factors that shape PV uptake, and the potential impacts on the electricity industry, existing infrastructure, and society more broadly, is now essential.

Most electricity systems in developed countries were built at a time when fuel was plentiful and cheap, and when the adverse climate impacts of carbon based fuels were unknown. This is now no longer the case. Increases in both population numbers and appliance ownership and use have resulted in growing demand for energy (International Energy Agency, 2014a), while decreasing upfront costs, global agreements to reduce carbon emissions, and financial incentives have resulted in a rapid uptake of privately owned residential PV systems across many countries (Tyagi et al., 2013; International Energy Agency, 2014b). Traditionally facilitated through feed-in tariffs, many households are pushing power back into the electricity grid; consequently, changes to requirements and standards around managing the grid are being increasingly considered (for example, the UK's Future Power System Architecture Project[2]). Network congestion, voltage rise, and rapid changes in output (e.g. due to fast moving cloud cover) are all problems that are starting to emerge because of PV proliferation (Eltawil and Zhao, 2010). More recently, decreasing prices for battery storage (Nykvist and Nilsson, 2015) combined with new business models (e.g. lease schemes, solar as a service options) provide the opportunity for more homes to install PV, and even become disconnected from the

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[2] https://es.catapult.org.uk/what-we-do/fpsa/

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grid altogether, leaving fewer customers to cover the costs of running and maintaining existing centralised generation assets.

These shifts in electricity systems are emerging through behaviour change of actors at the grassroots level afforded by both declining technology costs and new niche business models. However, to date, most approaches considering individual behaviour have tended to neglect the "complexity and influence of the social, economic, and political context in which those behaviours are manifest, arise, and develop" (Capstick et al., 2014: page 436). Similarly, most work to date exploring change in energy systems has tended to focus on technological innovation and economic processes, leaving social aspects and daily activities under-addressed (Shove and Walker, 2014).

In this paper we aim to explore how behaviour change and system transition approaches can be brought together to provide a more comprehensive view of change, exploring PV uptake in terms of actor behaviour (and behaviour changes) as well as in the broader context within which this is occurring. We analyse a combination of primary and secondary data to investigate the factors driving PV uptake in New Zealand, which has risen sharply since 2012 (New Zealand Electricity Authority).

The New Zealand case study is particularly interesting to explore because these sharp rates of uptake are occurring despite lack of financial incentives, resulting in a net-present negative value for consumers (Wood, Miller and Claridge, 2013). The continued rate of PV uptake in New Zealand points to an emerging transition in the energy system that requires a consideration of the dynamics surrounding consumer behaviour. In this paper we use the Energy Cultures behaviour framework (Stephenson et al., 2010, 2015a) alongside the multi-level perspective on socio-technical transitions (Rip and Kemp, 1998; Geels, 2011) to guide an exploration into the broad range of factors affecting PV uptake across a range of contexts. Bringing these perspectives together helps provide valuable insights as to how policy interventions might promote or constrain adoption, and the implications this may have for the future of energy systems.

2. Socio-technical transitions in energy

Socio-technical transitions describe a shift in the technology, markets, user practices, policy and cultural meanings relating to key societal functions (Geels, 2002, 2004; Elzen et al., 2004). Access to safe, reliable and affordable electricity underpins daily activity, enables modern society to function, and is one of the key enablers of economic growth (Modi et al., 2006; IEA, 2013). The shift from centralized power plants (mainly fossil fuel based) to distributed generation is a topical example of a socio-technical transition in energy underway globally. Understanding how these energy transitions occur, the patterns and mechanisms involved in the transition process from one set of energy behaviours to another, and the implications such transitions may have on future energy behaviour, are critical to ensure sustainable asset management and understand the potential technical, social, market and regulatory challenges.

Energy transitions have a number of unique characteristics that distinguish them from other types of transition or behaviour change in different domains (Geels, 2011; Verbong and Geels, 2010; Mah et al., 2012; Markusson et al., 2012). The first is that they tend to be purposive, driven by pressing environmental issues and sustainability goals that are expressed through national and international pressure. Second, solutions that offer the greatest collective good may not offer direct or tangible benefits to end-users, and this may have political and economic implications that require consideration. Finally, the energy sector tends to be dominated by powerful incumbent firms, many of whom have invested in existing infrastructure. Shifting away from this is not a fast or easy process, and may influence the degree to which incumbents support the transition, which could either constrain or accelerate the adoption of new technologies. Energy transitions thus encompass change across technology, practices, markets, and culture, implemented through a variety of interconnected actors. Understanding energy transitions requires a theoretical approach that incorporates this multi-dimensionality, as well as the structural change within which transition is situated.

2.1. A multi-level perspective on transition

The multi-level perspective (MLP) provides a useful lens through which to consider socio-technical transitions in energy systems. Drawing insights from evolutionary economics, sociology of technology, history of technology and innovation studies, the MLP supports the analysis of long-term system dynamics, shifts from one socio-technical system to another and the co-evolution of technology and society (Geels, 2002, 2005; Elzen et al., 2004; Geels and Schot, 2007).

In the framing provided by the MLP, transition is defined as the change from one sociotechnical regime to another (Geels and Schot, 2007). This regime shift incorporates technological developments, rules, and engineering practices, as well as broader characteristics such as the regulatory environment, policy, culture, markets, and user preferences (Rip and Kemp, 1998; Geels, 2002). Socio-technical transition results from the non-linear interactions between the socio-technical regime, niches (the locus for radical innovations), and the exogenous landscape (Geels, 2002, 2004, 2011).

The MLP has predominantly been used to study historical transitions within specific sectors (e.g. Ansaria and Garud, 2009; Geels, 2005, 2006a, 2006b; Konrad et al., 2008; Raven and Verbong, 2007; Sovacool, 2009; Verbong et al., 2008). It provides a broad framing to explore multiple pathways of transition resulting from different interactions between the three levels in the framework (Geels and Schot, 2007). While studies to date have tended to focus on transitions emerging from the alignment and expansion of niche technological innovations, an increasing number of authors are pointing to the importance of exploring how everyday activities may drive (or prevent) transition (Shove and Walker, 2010; Jones, 2009, Hargreaves et al., 2013; Geels, 2012). Furthermore, demand and lifestyle considerations, particularly relating to actors within civil society settings who have the potential to play a vital role in generating grassroots innovation and socially embedded behavioural changes, remains under-addressed (Berkhout et al., 2004; Shove and Walker, 2010; Genus and Coles, 2008; Seyfang and Smith, 2007). Indeed, further research is required to explore how social, value-driven innovations emerging from behaviour changes contribute to transition within mainstream systems (Seyfang and Longhurst, 2013).

Overall, the MLP provides a useful conceptual framework for exploring socio-technical *systems* in transition, directing attention to niches, regimes, landscapes, and their interactions, and exploring how innovations can be shaped by social processes (Geels, 2010; Lachman, 2013; Hargreaves et al., 2013). However, as Shove and Walker (2010) suggest, the links between social processes and technological transition is often more dynamic, and consequently, we see that additional insights from other theoretical perspectives are required to explore how activities of civil society actors are constrained by and interact with this wider system.

2.2. Everyday activities and theories of practice

One such perspective that has become widely used in exploring transition is Practice Theory, which builds on a wealth of socially-orientated approaches (e.g. Giddens, 1984; Bourdieu, 1992; Wilk, 2002), and has more recently been applied to sustainability transition (e.g., Pantzar and Shove, 2010; Shove and Walker, 2007, 2010, 2014). Practice theory provides a different and additional perspective to explore sustainability transitions. This approach considers how social practices are sustained, reproduced, or shifted through various processes and rituals occurring in everyday life, exploring the practice itself as the unit of analysis (Shove and Walker, 2014; Watson, 2012; Spurling et al., 2013). Consequently, it provides a perspective beyond the frequently used more

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