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Geography, urbanization and lock-in – considerations for sustainable transitions to decentralized energy systems

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ABSTRACT

The importance of moving towards sustainable energy systems is critical to achieving societal sustainability. Transitions theory is a useful approach to look at the potential and limitations of systemic transitions, and has been applied in a number of alternative contexts. In the current study, we examine transitions theory and its implications for the progress of decentralized energy systems in Japan in the period after the Fukushima accident of 2011. Empirical data from a targeted nation-wide survey is used to examine the progress and change in consumer preference and behavior since the disaster, as possible evidence for the potential transition paths likely to be occurring. Importantly, this study utilizes data that examines a spectrum of urban–rural and disaster–non-disaster areas in order to explore whether any differences in response patterns were present. Results indicate that although the desire of stakeholders has been to change the energy system, there are barriers to transformation. Variation between rural and urban sites and between disaster-affected and unaffected areas was examined, indicating that (at least under the chosen classification) there was surprisingly little difference. The results have implications for understanding transitions at a much broader level, and imply that, if the empirical data is a useful indicator, Japan is within a locked-in or reorganization transition. In order to move to a more radical conversion type change a new approach is likely to be required to nurture niche innovations effectively.

1. Introduction

The goal of transitioning to sustainable energy systems has produced a wide body of literature – both on the theory of transitions and on multiple alternative scenarios of technically-achievable paths to the future. In Japan particularly, since the Great East Japan Earthquake and Tsunami Disaster of 2011, and the subsequent Fukushima nuclear disaster, the topic of energy has taken on added importance. It is clear that systemic changes are necessary and desired, but such changes have been largely unachieved in reality, leading specifically to the question of "why?". This paper hopes to contribute somewhat to answering this question.

Transition theory is used as a basis for examining the potential and paths to transition to sustainable energy systems, which have otherwise largely been viewed from a techno-economic perspective, with the advantages and disadvantages of alternative technologies mooted within this framework. Despite these arguments being technologically and regionally specific, it is rare for studies to give consideration to the specific human geo-physical and social context of the locations in which such transitions are expected to play out. For example, the climatic data may be considered, but the effect of urbanization on the economic, infrastructural and institutional barriers or enablers for transitions is not typically assessed. This paper presents a review and theoretical analysis of the need for considerations of geographic and social context using the example of varying levels of urbanization.

A survey was undertaken across Japan in March 2014 in order to understand the barriers to achievement of transitions to sustainable energy systems – particularly decentralized energy systems. The results of this survey are presented with analysis to explore the potential difference in "lock-in" characteristics across sites with varying levels of urbanization within the Japanese context. Moreover, the effect of the 2011 disaster was assessed from the data. The paper adds to the wider literature on transition theory and offers insights which are focused on, but not limited to, the Japanese situation.

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1.1. The structure and purpose of this paper

To build a more sustainable society, we must envision the future of the nation's energy system, consider ways to reform or transform it, and explore whether and how we can govern the change processes. To address these issues, recent work on transitions to sustainability has emerged, where the dynamics of the whole system are being analyzed from integrated perspectives considering dimensions of both production (supply) and consumption (demand). Transition theory offers one holistic lens as a basis for understanding system transitions from one state to another.

A further development of transition theory can benefit from greater understanding of the service users' (customers and consumers) awareness and preferences for the services and functions provided to society by a socio-technical system. As described by transition theory, the dynamic equilibrium of the power system's regime is constantly exposed to changes in transformation pressures occurring in the exogenous environment, at the landscape level. To be able to achieve a regime which brings about a new dynamic equilibrium and stability, a niche experiment harboring (nurturing) socio-technical innovations that can lead to pathways (processes) to effective system transitions is required. However, without considering the demand side and electricity consumers' awareness, preferences and behavior, it is impossible to understand the consequences, or nature of such transition pathways.

Whilst this element is important, there appears to have been little in the way of previous empirical studies on this specific point. Therefore, in this paper, we undertake empirical analysis utilizing the results of a survey undertaken in March 2014 in Japan, looking at the effects of the unprecedented transformation pressure provided by the Great East Japan Earthquake and subsequent Fukushima Nuclear Power Plant accident (March 2011). After the earthquake, Japanese residents across the country expressed skepticism of the existing power system. In answer to this doubt, researchers and specialists at the time, including Non-governmental organizations (NGOs) and non-profit organizations (NPOs) began to identify preferences for a transition from a large scale centralized energy system to a small scale distributed system (Ueta and Kajiyama, 2011). Three years after the disaster, the doubts and hope for policy change to the current system is expressed through consumer's knowledge and behavior. However it is unclear whether these desires for change will be sufficient to shift the equilibrium sufficiently to realize a new system (Vivoda, 2014; Wakiyama et al., 2014).

Following from the recognition of the problem outlined above, this paper utilizes transition theory, as presented by Geels et al. (Geels, 2002; Verbong and Geels, 2010) to explore consumer preference as an indicator and potentially influential to system reform along the variety of transition pathways. We outline in detail, with connection to theory, the survey structure used to empirically test consumer preference as a directional indicator. In this study we do not address the issue of agency, which has been discussed in detail by other authors (Grin et al., 2011). While we do not address this directly, we recognize the importance of power relationships in enabling or blocking transitions (discussed by others (Lawhon and Murphy, 2012)) – particularly in a system that is technically complex and centralized, and has a longstanding political power structure (Vivoda, 2014). Demonstrating the actual ability of consumers to create a change in regime is not the topic of this study, but rather, identification of consumer preference on key elements relating to the energy system and its transitions. The critical assumption is that consumer preference may offer an indication of direction which, if given sufficient agency, may result in a transition of one type or another. Although it is largely as an indicative measure that we use consumer preference, there has also, in recent times, been a greater impact of community preference on the outcome of policy decisions in Japan. (For example, communities hosting nuclear power plants have significant veto rights on their restart, and a widespread community consultation was undertaken by the previous government before developing their future energy plan (National Policy Unit, 2012).) Moreover, in moving towards liberalized energy markets and decentralized energy systems, the consumer preference is likely to be more important than previously in shaping the energy system transition. The survey results are presented along with analysis, and finally, the derived policy and governance implications are discussed with some reflections on methodological and theoretical perspectives.

1.2. Japanese energy situation

By way of background, Japan's current energy system and the transitions to date are described. Japan has been a country of great interest to energy and energy policy researchers globally, due to the various challenges that the country faces – lack of domestic energy resources as a major impediment to energy security being the foremost – as well as the successes that it has demonstrated in achieving very high levels of performance in energy efficiency across the generation to usage spectrum of technologies (Kikkawa, 2012).

In post-war Japan, rapid reconstruction and industrial modernization was undertaken, with economic growth at a rate of around 10% per annum (Surrey, 1974). From 1945 to 1958, domestic coal resources and hydroelectricity were the emphasis of government policy, which favored the strengthening of local industry (Surrey, 1974). At the beginning of the 1960s coal (32%) and hydroelectricity (51%) provided the bulk of electricity generation, with a high level of domestic energy independence. In order to maintain global economic competitiveness, and under pressure from foreign governments and companies, the Japanese government moved to adopt policies encouraging lower cost energy from the 1960s. A reduction of import barriers led to the low cost oil of the 1960s becoming the dominant energy source by 1970, with a 59% share in electricity generation alone (IEA, 2010).

After the second oil price shock in 1979, the government further tightened energy policy to promote greater efficiency and fuel switching (Perkins, 1994). Renewable energy was also viewed as a potential alternative energy source, and expansion in wind, geothermal and later solar hot water systems and photovoltaics contributed a small amount to energy supply (Ushiyama, 1995). While nuclear power was one of the central and largely successful alternatives to oil-based electricity, the siting and public acceptance issue caused significant blockages to expansion, with the lead time for acceptance rising from 2 to 3 years in the 1960s to 14–15 years in the 1980s (Lesbirel, 1990). Thus although the options for fuel switching had been relatively successful (gas and nuclear accounting for a little under half of electricity generation), the nuclear roll-out was facing a high barrier to new entry in the market. Nuclear power opposition increased because of the 1986 Chernobyl accident and a number of accidents occurring at domestic reprocessing and fast breeder reactors (Pickett, 2002). Despite this, the government continued to support nuclear energy and there were calls from the Ministry of Energy, Trade and Industry to develop at least 10 new nuclear power plants by 2010 (Nakata, 2002). As a convenient alternative to oil, liquid natural gas (LNG) increased further in favor because of its relatively low price, availability and lower emissions.

Examining the past energy transitions by way of comparison to the current situation, Fig. 1 shows the energy consumption trends – as total primary energy and electricity consumption (data from the IEA (IEA, 2012)). In this figure we can see the evidence of two